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EDUCATION

SCIENTIFIC AND TECHNICAL

OR

HOW THE INDUCTIVE SCIENCES ARE TAUGHT AND HOW THEY OUGHT TO BE TAUGHT

BY

ROBERT GALLOWAY, M.R.I.A., F.C.S.

HONORARY MEMBER OF THE CHEMICAL SOCIETY OF THE LEIGH UNIVERSITY, U.S.

AUTHOR OF "A TREATISE ON FUEL, SCIENTIFIC AND PRACTICAL;" "A MANUAL OF QUALITATIVE ANALYSIS;" "THE STUDENT'S GUIDE IN THE HIGHER BRANCHES OF CHEMISTRY;" "A PLAN FOR RENDERING SALTED MEAT MORE NUTRITIOUS, THEREBY PREVENTING SCURVY;" "THE FIRST STEP IN CHEMISTRY; A NEW METHOD OF TEACHING THE ELEMENTS OF THE SCIENCE," ETC. ETC.

"As the best sciences which the ancient world framed supplied the best elements of intellectual education up to modern times, so the grand step by which, in modern times, science has sprung up into a magnitude and majesty far superior to her ancient dimensions, should exercise its influence upon modern education, and contribute its proper result to modern intellectual culture. . . . . By such study of one or more departments of inductive knowledge, the mind may escape from the thraldom and illusion which reigns in the world of mere words. . . . . The knowledge of which I speak must be a knowledge of THINGS, and not merely of NAMES OF THINGS."—WHEWELL.

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1881

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I take the liberty of Dedicating this Work

TO THE

CHEMICAL MANUFACTURERS

OF THE UNITED KINGDOM

BECAUSE

I have many personal friends engaged in these industries,

AND

Also because I have attempted, in this book, to improve the teaching of the Sciences on which their Industries are based.

ROBERT GALLOWAY.

PREFACE.

De Quincey, in the Preface to one of his works, expresses the difficulty of framing suitable titles for books; the late Charles Dickens expressed a similar opinion. If such artists as these in words felt a difficulty, one less skilled in the choice of them may well be excused if the title he has given to his book does not fully indicate all the separate portions of it.

The difficulty of framing a suitable title for the work was due to the subject on which it treats. Education, of all the many-sided subjects, is the one that has the greatest number of sides. In discussing Scientific and Technical Education, the Author felt it impossible to avoid referring to the oldest branches of higher education, classics, and mathematics. This was rendered necessary for two reasons; the first being that they are the subjects which have been longest taught in secondary schools and universities. The Author conceived that if he could show and prove that eminent authorities on these subjects considered that the modes of teaching them admitted of improvement, which he thinks he has done, it might very fairly

be supposed that the teaching of the comparatively newer branches of learning, as those of the Inductive Sciences, might not be perfect. He has also shown, he thinks, from the opinions of the eminent authorities he has quoted, that some of the Inductive Sciences are very imperfectly taught; but he has had to depend upon his own opinion alone for the imperfect way he believes Chemistry is taught. He must therefore leave it for Public opinion to decide whether he has, like the distinguished authorities on the other subjects, made out a case. For this reason, if for no other, he has devoted one Lecture to the operations of the mind, so that those who are not conversant with Chemistry can test which of the two methods—the one he condemns, or the one he proposes—for teaching that science is most in harmony with the laws of thought.

The second reason which induced him to refer to classics and mathematics was to show that the mind is only trained by the study of those subjects in deductive reasoning, and is, therefore, imperfectly trained when education is confined to them; and of the two modes of reasoning, deductive and inductive, the latter, it has been shown in the book, is the more important, even in the ordinary affairs of life.

The first two Lectures, in a less extended form, were given to his then students; this was the

reason why the book came to be framed in the form of Lectures. It only remains for the Author to add that he trusts his work will assist in arresting the competitive examination system, at least in the Science Schools carried on by the Department of Science and Art, and by the City Guilds; a system which, with the exception of England, only retrograde nations like China adopt; and that it will aid in causing us to follow in our educational systems the examples set by enlightened nations like Germany.

ROBERT GALLOWAY.

DUBLIN, *April*, 1881.

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SCIENTIFIC AND TECHNICAL.

LECTURE I.*

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THE subject of the present course of lectures is one that has attracted great attention in this and other countries. There has consequently been much written and spoken on the subject, especially in England; and if all that has been stated be true with respect to OUR POSITION, we are still

* The reason why the matter of this book has been given in the form of Lectures is stated in the Preface.

far behind most of the continental nations in scientific and technical education.

Although we have had COMMISSIONS, SPEECHES, REPORTS, &c., in abundance, I think one part of the question, and the key, in my opinion, to the entire subject, has hitherto received little or no attention. As I have had a long and varied experience as a teacher of science, and not been altogether an unsuccessful one, and having also had some considerable practical experience in CHEMICAL MANUFACTURES, I am perhaps as well informed by the knowledge acquired in these respective positions, as to the kind and quality of the education required, and the best modes of teaching it, as most of those who have written or spoken on the subject.

The reasons which have been assigned for our backwardness in SCIENTIFIC and TECHNICAL EDUCATION by those who have come forward to enlighten the PUBLIC, whether by giving evidence before ROYAL or OTHER COMMISSIONS, or by PAMPHLETS, or on PUBLIC PLATFORMS may be grouped, speaking generally, under two heads. One of the reasons assigned for our backwardness is due, it is stated, to continental nations having cultivated technical education for a longer period than we have. The neglect of this education is due, it is stated by the other class, to the State not having supplied sufficient money for the cultivation of art

and of those sciences upon which depend the invention of new manufactures, improved processes in those already existing, and greater economy in carrying out those already in use.

I do not think these reasons are sufficient to account at the present time for the inferior position we are said to occupy in this respect, when compared with other countries. The subject is no new one with us; to go no farther back than 1853, the SOCIETY OF ARTS, LONDON, in January of that year, appointed a Committee to see in what way the Society could aid in the promotion of TECHNICAL EDUCATION in the country. In order to carry out this object the Committee "received a large mass of evidence from ENDOWED GRAMMAR SCHOOLS, from PRIVATE SCHOOLS, from MECHANICS' INSTITUTIONS, from the friends of education of every grade, and especially from a considerable number of the leading manufacturers of the country." The Committee, in their Report, state "they must premise the observation, that an interest in the improvement of education is by no means a novel feature in the annals of their Society;" and give an extract from the volume of the Society's Transactions for the year 1787 to prove this. This shows that we were a long time ago alive, at all events, to our want of this kind of education.

I have refreshed my memory by again perusing

carefully this Report and evidence, and I cannot find that any of the evidence goes to show that we were in a worse position at that time in respect of Technical Education when compared with Continental Nations, than we are at present as compared with FRANCE, according to Mr. C. W. Siemens, in his Address before the Iron and Steel Institute, at Paris, September, 1878, and yet the amount of money spent by the nation on scientific education has increased enormously, as I shall show in bringing under review the next reason adduced to explain our backwardness.

If we are so far behind FRANCE, we must be in a still worse position as regards GERMANY; for in the REPORT ON TECHNICAL INSTRUCTION in that country and others which the French Government ordered to be prepared some years ago (1863), the sub-committee who drew up the Report, and who visited Germany and other countries in order to collect the most precise information on the subject, stated that, taking TECHNICAL EDUCATION in its entirety, France was behind Germany. Even as regarded primary instruction, they stated in their Report, that the most eminent Principals of French industrial establishments positively declared, that the deplorable and far too general absence of primary instruction, even amongst intelligent workmen, was one of the greatest and most lamentable obstacles to the

development of their faculties and the progress of industry. "If," they state, "we compare the results of primary instruction in Germany with those which are every year carefully ascertained and collected by the Ministry of War, we are compelled to acknowledge the great inferiority of our population in this respect, and the slow progress of primary instruction in France." They further remark, that French scientific men have been struck with the great scientific movement observed in Germany; "as we," they state, "have ourselves been, by the progress made in teaching the applied sciences. We think that in respect to both these points there is a movement taking place in Germany to which France ought to pay serious attention."

If the cause of our backwardness in the cultivation of Science and Art and their applications were due, say thirty years ago, to the State not having supplied money sufficient for their proper and complete cultivation, such a reason, I think you will conclude with me, ought to have ceased to operate at the present time, when I place before you facts which show the advances we have made in that respect.*

* In the opening address at the commencement of the Winter Session (1880) of the Society of Arts, the Chairman of the Council said, that he was "thoroughly ashamed that a comparatively poor country like Switzerland, having a total population, according to the last census, of considerably less than three millions, should

During the financial year ending the 31st of March, 1851, there was expended, on what may be termed technical education, £34,855. In the same year Parliament voted for public, that is, for primary, education for Great Britain £125,000, and for Ireland £125,000; and it must be borne in mind that the grant voted by Parliament for National schools in England was then, especially, a comparatively small sum compared with that which was raised by the voluntary contributions of the people.*

During the financial year ending the 31st of March,

possess an institution (the Polytechnic Institution at Zurich) of such magnitude, while in England it is difficult to point to the existence of any such institution at all; and while, twenty-four years after the example was set us in Switzerland, we are about to establish in London, at last, a central institution, which, whether we regard the magnitude of the building, the number of scholars, or the number of subjects to be taught, will represent but a fraction of the one at Zurich. In the Institution there are nearly 1,000 students, of whom 349 are from countries other than Switzerland, including five from Great Britain. The annual expenditure amounts to £18,000. The revenue is slightly in excess of the expenditure—£3,800 is paid by the students, £13,800 is contributed by the State, £800 from the Canton and town of Zurich, and about £120 from other sources."—*Design and Work.*

* "How grand have been the undertakings of voluntary exertions for the education of the people is sufficiently attested by the activity of two societies formed at the beginning of this century, *The National* and *The British and Foreign School Society*, as well as of the *Ragged School Union* (since 1844). The Archbishop of Canterbury was able very recently to declare in the House of Lords, that within the last fifty years £27,000,000 had been laid out by members of the Church of England for the education of the poor."—Dr. L. Wiese.

1855, there was expended on Science and Art institutions, *scientific and technical education*, which were then being grouped under the DEPARTMENT OF SCIENCE AND ART, which *Department* had been created in March, 1853, £80,000. In the same year Parliament voted for public (primary) education in Great Britain £263,000; and for Ireland £193,000.

During the financial year ending the 31st of March, 1879, there was expended on Science and Art institutions, SCIENTIFIC AND TECHNICAL EDUCATION, forming the Department of Science and Art, £307,414.* In the same year the Government grant for primary education in England and Wales was £2,149,208; for Scotland, £497,612† (for Great

* In 1878 there were 57,230, and in 1879 51,519, pupils attending the science schools and classes in connection with the Department of Science and Art; and in 1879 there were 795,444 pupils receiving instruction in art in schools and classes connected with the Department; there was an increase in art students on the previous year of 67,570.

† The State in the year 1833 for the first time assisted elementary education with a grant of money. The grant, chiefly for the building of schoolhouses, amounted then, according to Lord Althorp's proposal, to £30,000 (£20,000 for England and Wales, and £10,000 for Scotland). But it was not until the year 1847 the Government asked from the House of Commons a grant of £100,000 for the education of the people. On the 19th of April of that year the late Lord John Russell, having explained the reasons for this application, moved the order of the day for a Committee of Supply. The late Mr. Thomas Duncombe, Member for Finsbury, moved the following amendment:—

"That previous to any grant of public money being assented to by this House, for the purpose of carrying out the scheme of

Britain, £2,646,820); and for Ireland, £651,000. There are also the Board Schools supported by the School-rate, and this rate has already amounted in London to four and a half per cent. on the value of a house or dwelling.

The Parliamentary grants during the financial

national education, as developed in the 'Minutes of the Committee of Council on Education, in August and December last, which minutes have been presented to both Houses of Parliament by command of Her Majesty, a Select Committee be appointed to inquire into the justice and expediency of such a scheme, and its probable annual cost; also to inquire whether the regulations attached thereto do not unduly increase the influence of the Crown, invade the constitutional functions of Parliament, and interfere with the religious convictions and civil rights of Her Majesty's subjects."

After a debate of three nights, Mr. Duncombe obtained permission to withdraw the latter part of his amendment. The first part was put and negatived by 372 votes to 47.

The first objection Mr. Duncombe raised against the grant was the cost; the late Lord Macaulay, in his speech on the subject, observed with reference to the cost: "Surely, Sir, no person who admits that it is our duty to train the minds of the rising generation can think £100,000 too large a sum for that purpose. If we look at the matter in the lowest point of view, if we consider human beings merely as producers of wealth, the difference between an intelligent and a stupid population, estimated in pounds, shillings, and pence, exceeds one hundredfold the sum proposed. Nor is this all."

In this the first scheme of National education for every pound the Treasury paid, the managers of the school, residents in the district, had themselves to pay two pounds. They had also out of their own funds to provide the schoolmaster with a house before they could obtain for him a grant from the public funds.

"There are at present in England one hundred and two *Inspectors of National Schools* (ten seniors with an annual salary of £700 each—the salaries of the juniors varies between £200 and £600); there are eighteen Inspectors for the schools in Scotland."

year ending the 31st of March, 1879, for other National institutions, &c., for the cultivation of the mind, were as follows:—Learned Societies, £17,050; University of London, £10,944; British Museum, £112,990; National Gallery, £11,983; National Portrait Gallery, £2,000; Paris International Exhibition, £36,700; Deep-sea Exploring Experiments (Report), £4,000. For Scotland there was voted:—for the Universities, £18,574; Board of Education, £2,435; National Gallery, £2,100. For Ireland there was voted:—for the Queen's Colleges and Universities, £17,779; Endowed Schools' Commissioners, £640; National Gallery, £2,389; Royal Irish Academy, £2,481. Making a total with the preceding sum of nearly four millions of pounds; and this does not include the entire cost of most of these institutions. The grants for the buildings, and keeping them in repair, the furniture, fitments, stationery, printing, &c., are voted under other departments.*

Then, again, we cannot neglect to take into account such valuable non-Government institutions as the Owens College, Manchester, now called the Victoria University, the capital funds of which, as far as I can make out, amount to nearly £400,000;

* In the Supplementary Estimates for the year ending 1879 there was a further sum voted of £131,940 for Education; £16,984 for the Paris Exhibition; and the total expenditure of the Royal Commission was estimated at £66,983; and there was a further sum required for Public Buildings, &c., amounting to £28,662.

the Yorkshire College of Science;* the similar institution at Newcastle-on-Tyne; King's College and University College, London;† the College in Wales; the one in Bristol; the College of Science at Birmingham, the building and endowment of which is due solely to the munificence of one gentleman, Sir Josiah Mason; and the one at Sheffield, also founded by private munificence; the College at Nottingham; and the very large sums which Sir Joseph Whitworth has given for the improvement of TECHNICAL EDUCATION. If the capital funds of these non-State institutions, the revenues of our older Universities and the Colleges attached to them, the revenues of our Grammar and other Endowed Schools,‡ and the money received in the form of fees in the Public and Private Colleges and Schools, with the amount which is subscribed by the public to the voluntary primary

* The Clothworkers' Company voted in 1879 £3,500, beyond the £10,000 previously voted, for the buildings connected with the Leeds College of Science, which are to be devoted to dyeing and the textile industries. This Company have also agreed to maintain this division of the school for five years at a cost of £1,200 per annum.

† King's College had spent in 1874 on its capital account £169,085; University College had spent in 1874 on its capital account £162,534; and the College of Physical Science, Newcastle, had, up to 1874, available funds of about £70,000.

‡ "The amount of the endowments of the endowed schools of England proper is estimated at about £1,000,000. The revenues of the Colleges and Universities of Oxford and Cambridge are derived from lands, houses, tithes, other foundations, and from the fees of the students. In the year 1871 the revenues of Oxford

schools, could be stated and added to the preceding sum, the amount would be almost *startling*. We will take the *voluntary primary* schools in England as an illustration; it has been stated that if they were extinguished there would have to be provided by rates independent of the State grants £6,750,000.

From a survey of these facts, the conclusion arrived at must be, that if the expenditure of money is all that is required, we ought to have the best General, Scientific, Professional, and Technical Education of any country. And yet the list I have given is a very incomplete one of our educational institutions, and of the amount which is contributed for educational purposes. As an instance I may notice the sum, £1,000,000, Parliament recently voted for the improvement of intermediate education in Ireland.*

and Cambridge were estimated at £754,405, and the anticipated increase during the next fifteen years at £160,000. The fellowships of the two Universities, about eight hundred in number, have, together, endowments amounting to about £204,000; about 900 scholarships and exhibitions were given, of the value of from about £40 to £150 annually. The sum paid to professors amounted only to £7,100; while the heads of Colleges at Oxford received £33,265, and at Cambridge £20,415, for their functions—which are, for the most part, only of a representative nature."—Dr. L. Wiese.

* In the Parliamentary session 1879 there was voted nearly one and a half million of pounds for improving the salaries, &c., of the national schoolmasters in Ireland; and there will have to be voted a considerable sum for fellowships, scholarships, &c., in the New Irish University; and a kind of promise has been made that a grant will be asked for to improve higher education in Wales.

That, as a nation, we are in earnest in desiring to have the best Scientific and Technical education to be obtained, is shown by the willingness of our Merchants, Manufacturers, Public Companies, and others, to subscribe funds for the attainment of this object. At a meeting held at Bradford on the 5th of October, 1878, there was subscribed at the meeting £12,000 towards the cost of a technical school for the town. I will name one more instance of the willingness of the people, either individually or through public bodies, to subscribe, and that one is the founding of scholarships by some of the Companies of the City of London.*

These indisputable facts support me, I believe, in the opinion I have formed, that it is not from the want of money that we are behind Continental Nations in the cultivation of abstract and applied science. Neither can the backwardness be owing, in my opinion, to any inferiority of our mental

* The City and Guilds of London Institute expended on technical education in two years, ending the 20th of February, 1880, £25,205 17*s.* 1*d.* Upwards of 2,250 artisan students are now receiving instruction in classes, under the superintendence of the Institute. This fact does not express the extent of the work carried on, for out of the 815 candidates who presented themselves at the examinations held last May, only 595 had been instructed by its registered teachers.

The Institute intends to expend on the *building* of a Technical University at South Kensington £50,000; the *site* has been given to them by the Commissioners of the Exhibition of 1851. They are also going to expend on a central building for technical education at Finsbury £50,000; and an additional sum of £5,000 on laboratory extension at their Middle Class School in Cowper Street.

powers as compared with the people of other nations. It will be admitted, I think, that the civil and mechanical engineers of this country, for example, are not inferior to continental ones. That we have the inventive faculty is shown by the numerous mechanical and chemical inventions that are yearly produced, and very frequently by those who have been self-taught in science. The total receipts received by stamps for inventions in 1879 were £179,875 14*s.* 6*d.*; the total expenditure at the Patent Office amounted to £40,109 7*s.*, leaving a balance of £139,766 7*s.* 6*d.* The total receipts for the twelve years from 1868 to 1879, inclusive, amounted to £1,779,891 16*s.* 4*d.*; the expenditure amounted to £504,322 5*s.* 2*d.*, leaving thus a total excess of receipts over expenditure of £1,275,569 11*s.* 2*d.* Many of the inventions patented show, as might naturally be expected, that the inventors had only a very superficial or even incorrect acquaintance with mechanical or chemical science; but this only goes to prove the better results the inventors would have given to the nation if they had received a sound scientific and technical education.*

* The Americans at the present time are pre-eminent in inventing machinery which supersedes human labour; but their patents can be so easily and cheaply obtained, that any working mechanic can patent an invention: in England the poor man is all but excluded on account of the cost; it is only those with money who can venture to take out a patent. Our patent-laws demand an advance of £175 for a licence; in America it is £7;-and the

In connection with this question about our mental powers, I will give you the opinion of Dr. L. Wiese, late Privy Councillor in the Ministry of Public Instruction in Prussia. In his work, "German Letters on English Education,"* he says, "English youths exhibit a wonderful strength of will to make up for what they have neglected in education, and by their own efforts do that which others could not do for them. The number of self-taught men in England is greater than elsewhere."†

Admirable as our State Constitution is in many respects, it is not without its defects; one of these is the frequent want of UNITY OF DESIGN in our Government Institutions that are intended to promote the *self-same object*; the result of this is,

Government there are considering on the advisableness of reducing the rate to £3 10s. In 1879 the United States issued nearly 13,000 patents; England in the same year issued only 5,338.

* "German Letters on English Education." By Dr. L. Wiese. Translated and Edited by Dr. L. Schmitz.

† Professor Max Müller, in his "Lectures on the Science of Religion," when advocating the necessity of the introduction of Comparative Philology into English, as it has been into German, colleges and public schools, remarks: "The intellectual fibre, I know, is not different in the youth of England and in the youth of Germany, and if there is but a fair field and no favour, comparative philology, I feel convinced, will soon hold in England too that place which it ought to hold at every public school, in every university, and in every classical examination." It is only right to add, that since Professor Max Müller's Lectures were delivered, he states in a note the subject has been admitted to its rightful place in the University of Oxford.

that the means employed are not administered as economically as they would otherwise be, and they are not as efficient in accomplishing the object sought to be attained. This, I think, is the case at the present time with the Government Science Schools; no general idea it appears to me has guided the formation of these institutions; they have grown up as it were by piecemeal; the result is, there are no degrees of instruction observed in the different classes of science schools. In many of the primary science schools the higher branches of experimental science and their applications are attempted to be taught, and this kind of instruction in chemistry, which is purely an experimental science, is frequently based on no practical experimental knowledge by the student, but only on that kind of information to be obtained from books and oral instruction.* To illustrate the value of this mode of teaching the science, without the students themselves acquiring a knowledge

* The late Professor of Experimental Physics in the University of Cambridge, Professor Clerk Maxwell, in his work on the "Theory of Heat," in treating of Calorimetry, observes: "We shall illustrate this method (method of mixtures) by a few experiments, which can be performed by the student without any special apparatus. A few experiments of this kind actually performed by himself will give the student a more intelligent interest in the subject, and will give him a more lively faith in the exactness and uniformity of Nature, and in the inaccuracy and uncertainty of our observations, than any reading of books, or even witnessing elaborate experiments performed by professed men of science."

of it experimentally, would be equivalent in the teaching of drawing, in never placing a pencil in the hands of the learner; or in teaching vocal or instrumental music the learners were not taught to sing or play themselves, but were in each case simply lectured to, and examined on, drawing or music.

These primary science schools are in fact attempting to give what may be termed a Collegiate education in science based on no experimental knowledge acquired by the student, whilst the secondary schools and colleges of science are little more than primary science schools, as the teachers are obliged, owing to the ignorance of science on the part of the students, to be mainly occupied in teaching the A B C of their respective sciences, instead of being occupied, as they ought to be, in teaching, as regards acquired knowledge, the highest branches of the sciences and their applications, and in instructing the students how to extend the domain of science by teaching them how to discover new truths in, and to investigate unsolved problems of, science. This defect in our institutions is a great hindrance to the progress of scientific education in the United Kingdom, as our young men, as a rule, can only afford to devote a comparatively short time to education, it being a necessity with the majority to commence as early as possible making their own

living.* The complete and perfect organization of the different Educational institutions in Germany astonished the French Commissioners. They say in their Report: "The most striking characteristic of the German institutions for National education is the general whole—the arrangement of all the establishments, which, from the primary school to the highest faculties in the University, offer the different classes of citizens a series of degrees of instruction which they may need, or have the capacity to acquire." The system of graduated education is carried to perfection throughout Germany; it is therefore not surprising that Dr. Wiese should say of our unorganized educational system, "If we except the elementary schools, public instruction in general does not in any way show a progress towards objects clearly recognized and defined. *An extraordinary amount of power, time, and money is still wasted from a want of plan and unity.*†

* Dr. L. Wiese was told when in England, "The young in every country must be educated according to its circumstances. With us, they said, young men enter upon public life earlier than they do on the Continent. How many, when they have scarcely left the age of boyhood, are obliged to go out into the wide world—to India, to the Colonies, or any other distant part of the earth!"

† "On leaving the primary school, the child of poor parents can finish this part of his education in the Sunday schools, the middle-class schools, or superior primary schools. He next becomes an apprentice. If his family have sufficient means, he goes to the literary schools of two orders, according to his destination, and he thus attains the age of fourteen, either with a literary preparation,

Science cannot be applied with any success to the improvement of manufactures, whether by originating new industries, or in inventing new and more economical processes for those already existing, before the science has been acquired by those who are expected to accomplish these important results. Yet this is a mistake which we, as a nation, are, in my opinion, very likely to make at the present time; the mistake has been made before, and I think it is likely to be made again, from the hurry we are in, but especially from the *unorganized efforts* we are putting forth to accomplish the result. The mistake, I have said, has been made before. When the Schools of Design were first originated, they were mainly established, at least in the manufacturing districts, to instruct the students in designing patterns for calico prints &c.; the instruction was commenced by teaching the students the applications of art to the drawing of these patterns, and not art itself; the schools were consequently a failure, as must ever be the case, for originality cannot be the outcome of a system which teaches science through its applications.

As an illustration of what I have stated, that

which enables him to enter on his classical studies, and then to attend the Universities and Faculties dependent thereon; or with a literary and scientific preparation, which will enable him to apply himself to higher studies, and afterwards *technical applications*." —*The French Commissioners' Report on Education in Germany.* See Appendix I., on "German Schools."

Primary Science Schools are trying, or are being induced to try, to give what may be termed a Collegiate education in Science, I need only refer to the Directory of the Science and Art Department for this year; and as particular examples I will name Chemistry and Metallurgy. If students who are able to pass written examinations in conformity with these syllabuses, have in an equal degree been trained to *observe* and *experiment*, they have acquired a knowledge of Chemical Science more extended and profound than any one of our Universities give. *Observation* and *experiment* are the fountains of the INDUCTIVE SCIENCES; they are the two sources from which springs our knowledge of Nature and its laws. *Written examinations* are mainly the Department's *tests* of the student's knowledge of the Inductive Sciences; but by no written examination of any kind can it be ascertained whether the *examinee* has been trained to observe and experiment.

In the Tenth Lecture I will point out the changes that are, I think, required in the science branch of the Department; but I will here mention one or two of the reforms which are, I think, especially required. The Inspection and Examination of these Primary Science Schools ought not to be separated as at present, but they ought to be conducted by the same persons, and the examinations as well as the inspections ought to be con-

ducted in the schools themselves, for it is only there that the real intellectual standard can be ascertained.

The giving of prizes and medals to the students ought to be abolished, for the examinations ought to be disassociated from any kind of competitive examination; the examination should only mark the different grades of absolute merit in the examined. Let us in this respect *copy* what is really excellent and valuable in German Schools, and which is capable of being adopted in our own Schools. An English gentleman on visiting the Trade or Business school at Barmen (Elberfeld) asked the highly accomplished director of the school, Dr. Zehme, "whether they (the pupils) *were excited to work* by the prospect of PRIZES, HONOUR-LISTS, and COMPETITIVE EXAMINATIONS. *He replied that the principle of competition was almost entirely excluded from their educational system*, as tending to foster a *servile view of education*, and to lead to spasmodic and exhausting efforts and feverish excitement, *rather than to the healthy and harmonious development of the mental powers.*"* "In Germany the student's powers are carefully husbanded for employment in the serious toils and struggles of mature intellectual life: in England they are wasted in a ruinous and unmeaning rivalry of

* "German Schools." By Walter C. Perry. *Macmillan's Magazine*, June, 1877.

striplings."* Professor Huxley has very justly remarked that "we study in these days *not to know but to pass*, the consequence being that *we pass* and *don't know.*"

The abolition of prizes and medals ought to be accompanied with the proper recognition of the teacher. He ought to receive payment by salary, and not payment by results; the Education Department disapproves of payment by results in one of its departments, but adopts it in another of its departments (Department of Science and Art). Both cannot be right. "The Education Department," states the Principal, the Rev. Canon Barry, of King's College, London, "is very wise in resisting the enthusiastic advocates of *payment by results.*"

I would ask the attention especially of Educationists, and those who take an interest in Education, to the following two paragraphs, taken from the Department's Directory for this year (1880) :—

"The object of the grant is to promote instruction in Science, especially among the industrial classes, by affording a limited and *partial aid or stimulus* towards the founding and maintenance of Science Schools.

"*The amount is liable to be decreased, and eventually withdrawn. Payments to teachers, therefore, must not be looked upon as perpetual, or in any way*

* "Endowed Competitions at the Universities, and their Results." By Sedley Taylor, M.A. *Macmillan's Magazine*, March, 1874.

conferring on the teacher a claim to any payments beyond those offered from time to time."

It is seen from the last paragraph that the Science teacher of the Department has no certainty of any payment from the Department beyond the present, and he does not *even know* what he may receive for his present work, for it does not depend on the labour and time he has given to his classes. Other teachers who prepare pupils for examinations get paid whether their pupils succeed or not; but the Science teacher has to depend for the payment *he may receive from the Department*, not solely on the marks the *examiner* may give; as there are exceptional rules which exclude the teacher receiving payment on results in some cases. Uncertainty in the *duration* of an employment, and uncertainty as to the *amount* to be received for the labour that has been given, must ever act unfavourably in securing the best talent.

To what does such a system necessarily lead? The teacher must, in order to secure some payment, teach his pupils to "pass;" whether *they know* the subject taught is quite a secondary matter to that of "passing." He soon, of course, finds out which of his pupils have a *good memory for words*, and to these he devotes his especial attention. The money of the State should not, I think, be expended on the results obtained by

verbal memory—in other words, upon a cram system; neither should it be expended on preparing the more gifted. "It is our principle," stated an eminent German teacher, "to adapt our instruction to the wants of the average boy—to see that *he* is brought up to the prescribed mark at the proper time;" and if *we* want a good educational system—one that will be for the advantage of the nation, whether it be general, scientific, or technical—it must be also our principle; but this cannot be if we adopt the system of payment on results. I shall again refer to this part of the subject in another Lecture.

The payment on the result system necessitates many of the teachers giving so much time to teaching, in order to secure a living, that they have no time for prosecuting their own studies, so as to keep them on a level with the progress which is taking place in the subjects they teach. In Germany *three lessons a day* is considered very full work for a teacher. It is thought, in that "land of learning," that a teacher "should give no more lessons than he can give with the whole force and freshness of his mind, without undue exhaustion; and, above all, he should have time for prosecuting the private studies which enhance the value and efficiency of his work; and he is only called upon to give instruction in *cognate* subjects" (Mr. W. C. Perry).

Would our Nobility approve of the State taking away the endowments of the great Public Schools and Universities they send their sons to, and leaving them to provide teachers for themselves, or provide them only with teachers who received payment from the State on the result system? Yet if the education the Department of Science and Art undertakes to give means anything, it is as important for the artisan, and a large section of the middle, class, as the instruction given at our great Public Schools and Universities is for the wealthier classes.*

This result system is by no means a cheap system; but that, and other changes that are, I think, required, will be more appropriately discussed in the Tenth Lecture.

By the want of plan and unity in our educational system, many different kinds of educational institutions are competing with one another, frequently to the injury of the whole of them.

* "Why cannot the shopkeeper class educate their own children without charity? It may be answered, Scarcely any class in the country does educate its own children without some aid. Witness the *enormous endowments* of our universities and public schools, where the sons of our well-to-do people resort. Witness our national schools, supported by State grants, and by parochial and national subscriptions. On the other hand, the lower middle class, politically a very important one, is dependent to a great extent for its education on private desultory enterprise. This class, in this land of education, gets *nothing* out of the millions given annually for this purpose to every class except themselves.—*A French Eton*, by MATTHEW ARNOLD.

The Salford Working Men's College, for example, is at the present time complaining of the decrease in the number of their students, owing to the competition of the Science and Art classes established by the Manchester and Salford School Boards, to which the admission fees are exceedingly low. An immense amount of money is wasted, and yet we have only a beggarly result to show, either as regards general, scientific, or technical education.

There never was a period in the History of our Nation when a sound SCIENTIFIC AND TECHNICAL EDUCATION was so much required, if we are to keep our present position as a manufacturing country. America possesses, as has been observed by our present Prime Minister, Mr. Gladstone, all the raw materials, Iron, Coal, &c., which, as far as material resources are concerned, have made England the foremost manufacturing country in the world; America not only possesses these, and in abundance, but she possesses others—as Cotton—which we do not possess.* But America is not the only

* As an illustration of this with respect to coal, the following is an extract from Mr. Hussey Vivian's work, "Notes of a Tour in America:"—"The South Wales coal-field, which, I think, has the largest area in Great Britain, is, so far as I remember, about 80 miles long and 25 wide at most; the Pennsylvanian coal-field, measured on the map, is 750 miles long and 180 miles wide at its northern end; at 350 miles south it is still 100 miles wide; for another 300 miles it is 40 miles wide; after which it widens out again to 100 miles. But the Kansas and Missouri coal-field

civilized nation that we have to depend upon for important raw materials; Spain, for example, supplies us at the present time with one of these Materials, Sulphur ore, which is required in one of the great industries of Glasgow, Newcastle-on-Tyne, Widnes and that part of Lancashire, and also in Dublin; this substance, or rather one of its elements, is also required in another very extensive manufacturing industry in these countries. But in addition to the want of some of the raw materials we require for several of our manufactures, many of those we have are becoming impoverished in the valuable constituent they contain, either actually, or through competition with a richer material from foreign countries. It will thus be seen upon what an apparently frail support some of our most important industries rest, which at present constitute us one of the greatest manufacturing countries, if not the greatest, in the world. Not only is

looks much larger. It seems to be 600 miles long and an average of some 250 miles wide; while the Illinois field seems to be 300 miles long and 170 wide.

"Without counting the latest discoveries, which are not yet defined, and without counting areas of coal in the triassic or cretaceous formations, and in the tertiary, where there are lignites, there has been marked out by definite surveys an area of 228,059 square miles of coal measures. These measures range from 3000 feet in thickness, with 70 feet of coal, in the anthracite basins in Pennsylvania, to a few feet in thickness and a few inches of coal, in the Michigan basin. The aggregate area is greater than that of the new German Empire (225,000 miles), which supports a population of over 40,000,000."

superior scientific knowledge and skill required to make these impoverished materials again available, but each new improvement of old processes of manufacture, or the creation of new ones, requires a better acquaintance with science for their successful working, than the older and cruder ones did.

Again, all nations are striving to reach our level in those manufactures in which we have hitherto excelled, and, if possible, deprive us of our superiority; and we have given them advantages, in the form of free trade, which they have not returned us, at least in equal measure. There is an example—a curious one—which I cannot omit to notice: our manufacturers have not only to compete with hostile tariffs in foreign countries, but one of our industries, SUGAR REFINING, has to compete at home with the refined sugars of France, Belgium and Holland, on which bounties have been granted by the Governments of these countries to their sugar refiners on the sugar they export. This has had the effect of almost annihilating this industry, at all events for the present, in the United Kingdom. It is stated that about 30,000 workmen were thrown out of employment in the United Kingdom owing to the operation of these bounties.*

* "A few years ago there were some twenty-seven refiners in London making loaf-sugar; but, owing to the unfair competition of bounty-fed sugar, all but one have retired from business, or been ruined."—*Design and Work.*

Whether it is owing to the protective system adopted by other nations with regard to our manufactures, whilst we have opened our markets free to all nations, or whether it is due entirely to the superior technical education which other countries have adopted in comparison with our own, is earnestly engaging the attention of most of our leading men in the different classes of society. Certain it is that we have now powerful rivals in American and Continental markets in those branches of manufacture in which we were some time ago unrivalled, and had the command of the markets in every part of the world.* As an illustration of this, let me quote for you some passages from a speech which was given on August 26, 1878, at the second session of the Bradford Technical Schools, by Mr. Alderman Mitchell. Alderman Mitchell, after giving some statistics with regard to the woollen industries, went on to state, "that the exports of British and Irish produce had greatly declined during the past few years, and the decline was most noticeable in the exports to Germany, the United States, Belgium, and other Continental countries, which were themselves making such great progress in manufactures, especially in woollen goods. The Australian Colonies," he said, "with

* I believe we shall have more to fear in the future from the productions and manufactures of America than from the Continental ones.

their population of 2,000,000, were now taking more of our manufactures than the 40,000,000 of inhabitants in the United States, or just about as great a quantity as the 70,000,000 of people in Germany and Austria together. If in the course of the next ten or twelve years anything like the same decline in our exports to our old markets should take place, our Colonies would be found to be taking quite as many of the goods manufactured in this country as all the rest of the world united. The depression in trade did not account for the large falling off. If we would," he said, "be successful, we must adapt ourselves to the changes of taste and fashion that are for ever occurring, and not seek to keep the world bound to the acceptance of the same kind of goods from year to year. There is a constantly growing appreciation of beauty of colour and originality of design on the part of the public. . . . . France long ago recognized the necessity of providing special means of training for such of her citizens as desired to devote themselves to commercial pursuits, and this special training has begun to bear good fruit for them. In times not far gone by we were, in knowledge of the processes of manufacture and in inventive ability, far in advance of any other country; but France, Germany and America now run us very close, and in some particular matters of manipulation there is no doubt the French surpass us.

The cry," he said, "for technical education is therefore no empty one; it represents a necessity, and there is nothing more encouraging, I take it, in the present aspect of the Bradford trade than the support which is being given to the new Technical Schools, and the desire which is being evinced on the part of persons engaged in the local industries to avail themselves of the advantages thus afforded them."

A Report on the Cotton trade recently published affords conclusive evidence that in this important branch of manufactures foreign competition is both active and threatening:—Thus in 1860–61, of the total amount of cotton in the market, 5,699,000 bales, Great Britain took 2,817,000 bales, against 2,882,000 for the Continent and America, or 49·4 per cent. of the whole. In the ten years between 1860 and 1870 little change took place in the relative positions; for in 1870–71, Great Britain, out of a total of 6,246,000 bales, took 2,988,000, against 3,271,000 for the Continent and America, or 47·9 per cent. of the whole. But in 1877–78, out of a gross amount of 7,343,000 bales, Great Britain actually consumed 5,000 bales less than in 1870–71, or 2,983,000 bales; while the Continent took 2,473,000 bales, and the United States 1,657,000 bales—or together 4,130,000 bales; and India took 230,000. Thus the percentage of the

per cent. Putting the total cotton used in Great Britain at 1,250,000,000 lbs., one-fifth of this is for home consumption, the remaining four-fifths is manufactured for export. Now the decrease in the export to France, Germany, Holland, Belgium and Italy, between 1872–73 and 1877–78 is equal to 120,000 bales of cotton, of 400 lbs. each; while the United States trade has decreased from 226,800,000 yards of export in 1861 to 47,400,000 yards in 1877. India has also lately erected mills capable of producing 400,000,000 to 500,000,000 yards of calico. Thus it is quite evident that in this important branch of manufactures competition is very dangerous in every direction, and that if we mean to hold our own, it must be by a decrease in the cost of production, and an improvement in quality;* but if we accomplish these desirable results, the hostile tariffs of foreign countries may be raised so as to prevent any competition on our part.†

* Mr. Thomas Brassey states in his book on "Work and Wages," "that relative progress of the export trade is the most reliable standard by which the cost of production in different countries may be compared."

† Mr. Thornley of Southport, writing to *The Times* in August, 1879, on the Foreign competition of the Cotton trade, gives the export of Cotton goods from Great Britain in July, 1877 and 1879. They were as follows:—

Year.	Cotton yarn in lbs.	Cotton cloth in yds.
1877 ...	20,069,200	... 358,118,300
1879 ...	17,508,200	... 301,830,800
Decrease	2,501,000	... 56,287,500

Mr. Thornley goes on to state, what he wishes to point out is, that

The great depression which has existed in our Iron trade is known to all. We were, and still are, in a certain sense, "hewers of wood and drawers of water" for some Continental nations. We export to them large quantities of crude iron and coal, and they fashion the metal by a higher description of labour, and the fuel, into manufactures of Iron and Steel, excluding almost, at the same time, oursəf a like kind by hostile tariffs; so that, in an industry in which we ought to be pre-eminent as compared with these nations, on account of the abundance of the raw materials which we possess, they are now exporting to us more of these manufactures than we are exporting to them of this class of goods:—

Manufactures of Steel, or Steel and Iron combined.

Year.	Export value in £'s.		Imports, value in £'s.	
1869	...	49,362	...	14,973 (Germany)
,,	...	26,883	...	102,814 (Belgium)
,,	...	15,684	...	84,813 (Holland)
,,	...	78,690	...	101,248 (France)
1878	...	60,184	...	84,146 (Germany)
,,	...	26,861	...	543,998 (Belgium)
,,	...	25,457	...	607,285 (Holland)
,,	...	80,917	...	110,254 (France)

our Cotton manufacturers have every advantage over their competitors but one, and that one disadvantage lies in the influence of our present factory law. Ours are the only factories where work is restricted to fifty-six hours per week, and my contention is, he states, that this one fact is sufficient, and more than sufficient, to deprive us of our commercial supremacy, and, therefore, eventually of our Cotton manufacturing industry.

The decrease in our exports of crude and finished Iron to the United States is still more severe. In 1869 we exported value in pounds to the States—of Pig and Puddled Iron, 395,445; of Railroad Iron of all sorts, 2,250,032; of Bar, Angle and Rod, 434,028; of Hoops, Sheet, Boiler and Armour plates, 343,635; of Steel, unwrought, 513,713; of Hardware and Cutlery, 641,525; of Iron, cast or wrought, and other manufactures, 152,944; of Iron wire (except Telegraph wire), 54,278; of Tinned plates, 1,744,279; of manufactures of Steel, or of Steel and Iron combined, 92,521; and we imported in that year of this last class of Iron manufacture from the States (and it is the only class that has yet been imported from that country) value in pounds, 64,489. In 1878 we exported to the States, value in pounds, of Pig and Puddled Iron, 133,608; of Railroad Iron of all sorts, 9,157; of Angle, Bar and Rod, 43,186; of Hoops, Sheet, Boiler and Armour plates, 12,310; of Steel, unwrought, 171,537; of Hardware and Cutlery, 301,479; of Iron, cast or wrought, and other manufactures, 53,401; of Iron wire (except Telegraph wire), 21,091; of Tinned plates, 1,895,349; of manufactures of Steel or of Steel and Iron combined, 35,080; and we imported of this last class of Iron manufactures in the same year, value in pounds, 177,040. These statistics show that, with the exception of Tinned plates, our exports to the United States have decreased in every description

of Iron manufactures;* and this diminution, it is to be feared, is due to no passing events, but is owing in a great measure to the increasing production of Iron manufactures in that country. There are already in America fifteen Bessemer works; the chief industries of Pittsburg Mr. Vivian found to be Iron, Steel, and Glass, the two former expanding into various incidental manufactures. The coal at Pittsburg is good and extraordinarily cheap; an excellent rubbly coal, with very little dead small, with which they can puddle, and do any work whatsoever, is delivered in the works at 4*s.* per ton; in quality it is quite equal to our Midland or North Country coal, very hard and cubical in its fracture, bituminous and binding. Slack can be delivered at 16¾*d.* per 2,000 lbs.

The total value of our exports to the United States continually increased, until in 1872 they amounted in value to £45,907,988; since then they have continually declined, until in 1878 they only reached £17,531,904; the chief items of decrease being cotton piece goods, earthenware and porcelain, iron (wrought and unwrought), linen piece goods, wool and worsted stuff.†

* These statistics I have taken from a document published by the Wolverhampton Chamber of Commerce in the year 1879.

† Fifteen years ago the balance of trade was heavily against the States, and the total of her trade in any shape, export and import, put together, was very poor. In 1864 the total value of all the exports sent out from America was about £31,300,000, and the

The following Table, giving the total value in pounds of our Exports and Imports to and from the countries named in the years 1869 and 1878, will be interesting, I think, to most of my readers :—

1869.		1878.	
Total value Exports in £'s.	Total value Imports in £'s.	Total value Exports in £'s.	Total value Imports in £'s.
	RUSSIA.		
8,387,536	16,674,524	9,458,729	17,782,754
	GERMANY.		
32,071,519	18,354,014	29,169,665	23,516,439
	BELGIUM.		
8,912,978	9,391,515	11,355,569	12,371,900
	FRANCE.		
23,277,222	33,536,972	26,595,958	41,250,748
	SPAIN.		
2,770,794	6,346,741	3,794,734	9,098,934
	TURKEY.		
7,297,897	7,613,522	8,301,778	4,751,602
	AUSTRIA.		
1,593,265	2,276,806	1,089,372	1,673,738
	HOLLAND.		
17,383,493	12,739,744	14,676,125	21,245,563
	UNITED STATES.		
26,787,731	42,519,927	17,531,904	89,070,447
	BRAZIL.		
7,121,219	7,312,494	6,199,211	4,641,898
	CHINA.		
6,985,553	9,814,388	3,949,927	13,624,148

exports. In the same year the imports and exports of England were £274,900,000 for the former, whilst the latter amounted to £212,600,000; thus the commerce of England in that year was between five and six times greater than that of America. England sent out at that time to foreign markets almost as much as she was

In no part of the Empire is there a greater need, in my opinion, of a sound system of Technical Education than in Ireland: the raw materials required for most large industries, if they exist at all, exist but in small quantities, and those that were of importance, as the metallic ores, are either being exhausted or being superseded by richer material from foreign countries. Thus, for example, the Berehaven Copper Mine has had to be all but abandoned on account of the depth of the mine. The ore, although not poor in copper, cannot, from the expense of raising it, compete in price with the rich copper ores and regulus which are imported into England from other Countries. The mining of the sulphur ore (iron pyrites) in Wicklow, at one time a very important industry, has practically ceased; the rich sulphur ore of Spain being now employed, to the exclusion of the comparatively poorer ore of Wicklow. The Spanish ore contains also a small percentage of copper, and this being what is termed a secondary product, can be extracted with profit after the sulphur in the ore has been utilized; it is stated that more copper is now obtained from this source than

compelled to buy. Last year (1879) the exports from America so far exceeded the imports that she sold fifty-three million pounds worth more than she needed to buy; while with us it was quite the other way: we were obliged to buy very nearly twice as much as we were able to sell, the imports being £362,000,000, the exports £191,500,000.

from all the copper mines of Great Britain and Ireland.*

Before passing on to notice our agricultural productions, I will give a brief summary of Mr. Vivian's remarks on the Mineral Resources of America. Coal can be produced at a cheaper rate in some parts of America than in England.† America possesses iron ores of the finest steel-making qualities, and in vast abundance. That she will ever again depend on England for iron and steel Mr. Vivian believes to be impossible. She is beating us in hardware. He took some pains to go over the stock of an intelligent ironmonger in Canada, and in many articles he proved to him the superiority of those of American manufacture—saws, locks, joiners' tools, and the like. The American

* *The American*, a new weekly review published in Philadelphia, which displays strong sympathy for Ireland, thinks that the plan of buying out the landlords and replacing them by peasant proprietors would not restore prosperity to the country. "It would do nothing for the mass of wretched poverty which fills Irish towns with enforced idleness. It would not relieve the pressure of the people upon the land, which results from the want of other industries than agriculture. It would not lift Ireland out of the wretched position of a nation employed only in the least remunerative of industries. It would do nothing to create that variety of occupation which is necessary to the unity and prosperity of the body politic."

† The great disadvantage, Mr. Vivian remarks in his work, "Notes on a Tour in America," under which America must always labour as a coal shipping country, is the distance of the coal-fields from the sea-board; the nearest point, he states, seems to be 150 miles from Baltimore as the crow flies, probably 200 by rail.

saving-labour machines, as the sowing and reaping machines, are known to most of us; and with their automatic machinery they are beating the cheap labour of Switzerland in the manufacture of watches and clocks.

They possess all other important metals, with the exception of Tin, in equal abundance. The region of Lake Superior supplies her with some 22,000 tons of Copper annually of the very finest quality that Mr. Vivian is acquainted with; so much so, that American brass makers, by the aid of the high quality of this copper, and that of New Jersey Spelter, were able during the Russo-Turkish War to meet the specifications of the Russian and Turkish Governments for cartridges, punched out of the solid in such a fashion as no brass made from ordinary copper and spelter would stand, and thus the Americans had the largest share of the supply of cartridges for the war. Time was, and Mr. Vivian remembers it well, when the United States drew the bulk of its supplies of copper and spelter from England. Copper ore is found in various other localities besides Lake Superior.

Twenty-four thousand tons of Lead annually pass through the market of Missouri and the district centering in St. Louis, alone. The extensive lead mines of Utah and California are being rapidly developed; and but a few

United States obtained its supply of lead from England.

The Gold and Silver production of California, Nevada, Utah and Colorado are known. The production of silver in the United States, which in 1868 was only £2,400,000, was estimated to have been £7,000,000 in 1875; the whole production of the world being about £14,000,000. The production of gold in the United States may be taken at about £8,000,000 annually; while that of the world is estimated at from £17,000,000 to £18,000,000. A few years ago the United States did not produce either of these precious metals.

Quicksilver, which is required in the metallurgy of gold and silver, is at hand in the heart of the Pacific Mining Districts. In 1874 California produced 27,000 flasks of 76½ lbs. each, worth about 6*s.* per lb.—say £600,000 in value. California, after having supplied her own wants, had two-fifths of her production to export.

Mr. Vivian says: "When we reflect that thirty years ago scarcely one of the minerals to which I have alluded was produced at all, and that at this moment each one, in its respective class, excepting coal and iron, probably nearly equals any other similar production in the world, and that in this short period the United States has passed from an importing to an exporting country, it is difficult to foresee to what extent her mineral wealth

may develop itself in time to come, especially when we consider the vast areas over which, in all geological probability, these mineral deposits extend."

But competition is as rife with our agricultural produce as with our manufactured goods, and it is not to be supposed that competition has reached its limit in this direction in these countries. It is unlikely that the best and cheapest modes of preserving meat and other provisions have been discovered. This, like all other human inventions, must admit of improvement,* whilst the boundless

* The most extensive dealers "in American animal produce" are beginning to be in favour of exporting "dead meat" rather than live stock. But the loss of live stock during the passage from the United States and Canada has greatly decreased; it is now reduced to about 3 per cent. for cattle, and 2 per cent. for sheep.

The following table shows the shipments of live cattle and fresh beef in the four years ending with 1879:—

	No. live cattle.	Lbs. fresh beef.
1876 ...	31,593 ...	33,381,508
1877 ...	50,001 ...	49,310,990
1878 ...	80,040 ...	54,046,771
1879 ...	135,720 ...	54,025,832
Totals	297,354 ...	190,665,101

According to a despatch from the British Secretary of Legation at Washington, the exports in the month of May (1880) of beef and other animal produce from the United States to England exceeded by four million dollars the exports in May, 1879; in the same month there was an increase in breadstuffs of a quarter of a million of dollars over that of the same month in the previous year (1879); whilst for the eleven months ending then there was an increase in the exportation of grain and breadstuffs to the United Kingdom of 63½ million dollars over the same produce exported in the previous eleven months.

prairies, plains, hills, and savannahs of the world, which are continually becoming more accessible to us by the aid of rail and steam, fatten cattle for the butcher, without rent, taxes, labour, or wages. When Russia was without roads, she could only send her surplus of grain in dear years, as she had to convey it by pack-horses. She now yields her harvest to us by the iron road every season. In the year 1878 we sent out of the country, according to Mr. Caird, £120,000,000 for articles of food, being at the rate of £15 per family. It is evident that the reduction of meat and provisions to the lowest price—*plus* the carriage—they can be sold for in the most favoured regions for their production—can, in the United Kingdom, be only a question of time.

What the price of meat and provisions will be in Great Britain and Ireland in a not distant future no one can at the present time foretell. The vast prairies of Nebraska and Wyoming, where countless herds of buffaloes roamed a short time ago, are now being stocked with cattle, a cross between Texan cows and short-horn bulls of the first class. When these vast grazing-lands, where the cattle live out all the winter, and get fat on the prairie grass, become fully stocked, the production will be enormous; and one penny per pound at present covers the railway carriage, freight, and charges from Chicago to Liverpool. The

mind fails to realize the enormous number of cattle that will ere long be grazing on this vast prairie land; but if a conception can be formed of the number, we may perhaps faintly realize it when we learn that one gentleman—Mr. Dillon, President of the Union Pacific Railway—is himself interested in a herd of 12,000 head.* Hogs are in equal abundance; and a short time before Mr. Vivian's visit in 1878 to San Francisco, a flock of 500 sheep had been sold for £120, or 4*s.* 9½*d.* a piece; wool must, therefore, be equally moderate in price.

Increase in cattle will of course be attended with an increase in the production of butter and cheese. That this increase is taking place in the United States is proved, I think, by the decrease in the exports of Swiss cheese there. In 1872 the cheese exported by the Swiss amounted to 2,230,000 francs; in 1878 it only amounted to 1,700,000 francs; in fact, the making of cheese in the States has become quite a manufacture. Instead of each owner of milch cows making the

* Miss Arabella Bird, in her work "A Lady's Life on the Rocky Mountains," states in the chapter in which the business of cattle-raising in Colorado is described, that the cattle king of the State, Mr. Iliff, has 15,000 acres, and owns 35,000 cattle. He employs 40 men only in summer and 12 in winter, and 200 horses. Owners of 6,000, 8,000 and 10,000 cattle are quite common in Florida. There are half a million of sheep in the State, and between the

cheese, the almost universal practice is to send the milk to the cheese factory, where the cheese is produced.* At present it is usually sold in our own markets a penny or more a pound below the English ordinary, and, price for price, it surpasses the English in quality. The Canadian Cheddar is actually superior to the English Cheddar; the English selling at 10*d.* per pound, the Canadian at 7*d.*

About ninety years ago Arthur Young expressed considerable doubt whether agriculture would ever be a paying occupation in the United States; this opinion has proved to be as true as the one expressed by the late Dr. Lardner, that a vessel propelled by steam could never cross the Atlantic. The grain crop of the United States in 1879 was estimated at 400,000,000 bushels, and of this quantity they could export 140,000,000 bushels. Australia also had about 170,000 tons of wheat to export, and yet, "when the first Europeans landed in New Holland, they found a land producing no vegetables fit for food, no animal akin to those in the regions they had left, and no domesticated

* "The dairy industry of the United States represents an investment of over 1,300,000,000 dollars, and an annual production of butter and cheese of over 350,000,000 dollars in value, which is 50,000,000 dollars more than the wheat crop of the country; one-seventh more than the hay crop, three times more than the oat crop, one-third more than the cotton crop, and but one-fifth less than the corn crop. Over 350,000,000 pounds of cheese, and 1,500,000,000

cattle of any kind. Repeatedly the convicts were on the point of starving, and probably would have perished had it not been for the abundance of kangaroos and the fortunate arrival of a ship from Java. In 1804 flour was quoted in Van Diemen's Land at £112 per ton; three years later wheat was £4 per bushel, and appeared so likely to rise to a still higher price that a garrison order was issued making it a penal offence for the settlers to charge for it more than £32 a quarter. But times have changed. In 1878, New South Wales had feeding within its borders over 27,000,000 of sheep, and 4,000,000 of horned cattle; while the colony of South Australia alone in the following year was prepared to export, after satisfying her own demands, the quantity of wheat already stated."

Mr. Brassey, and others in this country, are of opinion that we have seen the worst as regards the American agricultural produce on the British farmer;* he, and those who agree with him, believe that the soil there is getting exhausted by continuous cropping, and therefore the cultivation of wheat is steadily receding towards the west, away from the eastern seaboard, from which its products could be shipped to this country at the greatest advantage; and also, that after a time the stock-

* In his opening address as President of the Statistical Society, 1879.

feeder will have to pay for his pasturage, which he now gets for nothing. But there is a saying, "Whilst the grass grows the horse starves;" and I am afraid if the British farmer has nothing better to depend upon for the protection of his industry than the exhaustion of the great wheat and other grain lands in America and Canada, in those localities where the produce can be shipped profitably to England, he will find he has been trusting to a fiction. When the exhaustion will be complete, if it ever will, is very far distant; twenty successive wheat crops have, according to the *Times'* correspondent and others, been grown on the same soil with no manure added, and with no interval of rest, and with no seeming injury to the land, and no deterioration in the quality or quantity of the produce. Soils are not soon exhausted, otherwise many tracts would have been exhausted long ago in Ireland; and even in England the same thing, I think, would have occurred, owing to the practice of restoring to the soil in the form of artificial manures only one or two of the least abundant of the eight inorganic substances in soils which plants require.

Mr. Caird differs from Mr. Brassey and Messrs. C. S. Read and Pell: he believes that the importation of agricultural produce will not only continue but increase in quantity, and he believes the

articles which will bear neither long storage nor carriage—milk, fresh butter, early meat; vegetables, hay, potatoes, sugar; and 'in the south-eastern counties, grass-farms, dairying, and market-gardening.

Although the British farmer raises as much—or perhaps more—per acre as those in more favoured regions, it will nevertheless be necessary for him, in order to compete with foreign importations, to conduct his farming operations more economically than at present, and increase his production at the same time; in order to accomplish this, he must look for aid from chemistry and the other sciences. The sewage must be utilized, and in the form best adapted for the land; and I believe this is quite capable of being accomplished; indeed, my friend and former student, Mr. S. H. Johnson, by his process has accomplished the recovery of the greater portion; and of what still remains to be done I hope shortly to effect.* Then, again, we

* Mr. Mechi calculates that it takes the annual produce of 20,000 acres to feed the inhabitants of London for a single day, and yet this produce, when it is excreted in the form of manure, is consigned to the streams; and it takes a celebrated agriculturist, Mr. Prout, £2 15*s.* per acre per annum for artificial manures in the shape of bones and bird and bat's dung from Peru to produce his crops. Mr. Mechi asks, "Are we a sane people, or are we so recklessly rich in agricultural production that the waste of millions is to us a matter of little import?" I believe that if we excluded from our sewers the rainfall and subsoil water the sewage could be easily utilized.

hear of unexhausted manures ; is it in accordance with sound commercial principles to add to the land in one year such an amount of manure that it remains unexhausted for several years ? Of course, as cultivated plants absorb their food more rapidly than wild plants, their period of existence being more limited, they require to have their food in greater abundance in the soil ; but that fact does not necessitate a large overdose of manure. And it does not seem to be in accordance with true science to restore to the land only one or two of the eight substances plants require ; farm-yard manure contains *all* the substances they want. Again, is the form in which phosphate of lime is put on the land the best ? I think superphosphate is not the best form ; owing to its great acidity it is exhausting the land of its potash, and likewise a portion of the phosphate becomes inert, as I shall presently show, by probably becoming to a considerable extent converted into phosphate of alumina ; I believe if phosphate of lime (bone-earth) was deprived of only one-third of its lime, it would be a more valuable and economical manure than the superphosphate. Drs. Laws and Gilbert manured a field for several years with superphosphate of lime ; the crop grown was turnips. In the first year it received 504 lbs. ; in the second 560 lbs. ; and in the third 1,232 lbs.—in all, 2,296 lbs. of the manure. In the three

crops of turnips there were removed from the soil, in each about 112 lbs. of superphosphate; in the three years, therefore, 336 lbs.; there remained consequently in the soil 1,960 lbs. for the crop of the fourth year. There was now presented this strange circumstance, that this field, though it contained after the third crop nearly four times as much superphosphate as was supplied in the first year, yet required to be manured in the fourth year with 280 lbs. of superphosphate, in order to yield a fourth crop. While 504 lbs. in the first year had a most marked effect, 1,960 lbs. present after the third crop had no effect on the fourth; the soil contained in the fourth year four times as much as in the first, or eighteen times more than the crop required, yet lost its productive power.

New industries are especially required in Ireland to occupy, if for no other reason, the place of those becoming dwarfed by competition; and there are many which might be as successfully carried on, as regards material conditions, as they are in France and Germany; the extraction and manufacture of the products from kelp ought to be a most extensive industry, owing to the abundance of the raw material in the country; and there are many others, as the manufacture of the coal tar dyes, which ought to exist.

The progress in industries, not alone in this

country, but in others also, seems only to be limited at the present time by the want of the necessary scientific and artistic knowledge.* And it is singular to see how new industries sometimes affect those parts of the inhabited portion of the earth that would appear to be the most remote from their influence. That ancient dwelling-place, the island of Cyprus, which, since it has been handed over to us by the Turks, has occupied a large share of public attention, is affected by that beautiful Chemical discovery, the artificial formation of one of the colouring matters (alizarine) in madder, which I alluded to in the Introductory Lecture to the course on Organic Chemistry I gave in the session 1877–78. Owing to this discovery they can no longer grow madder with profit in Cyprus; they have, therefore, had to abandon the cultivation of that root.†

I will conclude this Lecture with a quotation from the French Report I have already alluded

* "The extent to which the manufacture of coal-tar colours is now carried on is shown by the statistics of labour and production at one of the principal coal-tar works in Germany. There are employed over 1,000 workmen, in addition to forty supervisors and branch managers, twenty-five chemists, one engineer and thirty clerks and accountants. The yearly consumption of coal amounts to 17,000,000 kilogrammes; anthracine, 825,000 kilogrammes; naphtha and benzol, 950,000; chromate of potash, 280,000; caustic soda, 1,245,000; sulphuric acid, 2,250,000; muriatic acid, 4,050,000; nitric acid, 850,100; alcohol, 94,500; and sundry chemicals, 3,500,000."—*Design and Work.*

† See Appendix II.

to :—"What is certain is, that henceforth the most powerful nation will be, not that which owns the most extensive territory, nor even that which has the largest population, but that which shall be the most industrious, the most skilful, the best educated, the most capable of utilizing all the means of action which science places at man's disposal to aid him in triumphing over matter. The greatest producer will be the first nation in the world."

LECTURE II.

Science must be Acquired before it can be Applied—The best Method of Teaching any subject—Imperfect Methods were adopted in Teaching the older branches of Learning, as the Dead Languages and Mathematics, attested by Eminent Authorities—Mechanical and Philosophical Methods of Teaching—Jean Paul Friedrich Richter's views on the effect of such a Teaching System as the Postal one—The Postal System now in use—The Methods generally employed in teaching Botany, Zoology, Geology very imperfect—This view corroborated by Eminent Scientific Authorities—Students would be more attentive and painstaking if more of Reality and less of Artificiality were adopted in Teaching—The Lecture-taught Class-room Student of Geology, Mineralogy, and Mining contrasted with the Uneducated Fossil-collector or Miner—Illustrations—The essential Qualifications an Educator ought to possess—The Student requires Sympathy, exemplified in the case of Mozart, Shelley, Goldsmith, Gibbon—Dr. Schmitz on the Qualifications a Teacher ought to possess—True Education only practicable by a true Philosopher—In Germany Education has assumed the shape and dimensions of a Science.

In the former Lecture it was stated that before science can be applied it must be acquired. There are, of course, some who have such a great natural aptitude for applying what they know, that they can invent and apply, and often very successfully, without much acquaintance with the science of which their invention is an application. But these

men must not be taken as examples; they are exceptions to the general body of men. Mozart, for instance, learned to play and compose at the same time. The technical, must therefore follow the scientific, education, and to obtain the best scientific education in the time most young men in these countries can afford to devote to its acquirement, *it is all-important*, if there were no other reasons, *that the best systems of instruction should be adopted*, and *all the different grades of science schools be carried on in complete unison.*

We must not, for we cannot afford to, make the mistakes in teaching the Inductive sciences which have been made in teaching the older branches of learning—as the dead languages and Mathematics. It has been asserted by men of the highest eminence that one half at least of the years boys have spent at school have been wasted, and the school experience of most persons will confirm this statement. "We do amiss," said Milton, "to spend seven or eight years merely in scraping together so much miserable Latin and Greek as might be learned otherwise easily and delightfully in one year." I was reading lately a biography of the late Emperor Napoleon. When about nineteen years of age, and his education was considered finished, he discovered, as he said, "that he really knew nothing thoroughly well," and he set to work to educate himself. There are few who would possess the requisite

patience and perseverance to commence their own education after it was supposed to have terminated, however desirous they might be to be well educated; for in addition to having to contend with any mental inaptitude, they would have to unlearn —which is a far greater obstacle—in order to learn thoroughly. I can assure you there is nothing more difficult for a teacher to accomplish than to educate those who have been previously superficially taught.*

The best method of teaching any subject is that which harmonizes most with the faculties of the mind in their mode and order of unfolding and commencing the subject with something appropriate which the learner *knows*, and carrying him forward from the known to that which he has yet to learn. "The cerebrum of man," states Dr. Carpenter, "grows to the modes of thought in which it is habitually exercised; and that such modifications in its structure are transmissible hereditarily; hence conceptions which prove inadmissible to the minds of one generation, in consequence either of their want of Intellectual power to apprehend them, or of their pre-occupation by older habits of thought, subsequently find a

* The most difficult to teach I have found, as a rule, are those who have been accustomed to attend popular science lectures; for what they hear is generally very superficial; and, therefore, what they acquire must be *superlatively* superficial.

universal acceptance, and even come to be approved as "self-evident." The science of Arithmetic, as at present existing, may be regarded as the accumulated *product* of the intellectual ability of successive generations; each generation building up some addition to the *knowledge* which it has received from its predecessor. But it can scarcely be questioned by any observant person, that an *aptitude* for the apprehension of numerical ideas has come to be embodied in the congenital Constitution of races which have long cultivated this branch of knowledge; so that it is far easier to teach Arithmetic to the child of an educated stock than it would be to a young Yanco of the Amazons, who, according to La Condámine, can count no higher than three, his name for which is Poettarrarorincoaroac."*

Before entering upon an examination of the methods employed for teaching Chemistry and some of the other Inductive sciences, I had better notice an objection which might be urged against my views by those who have given little or no attention to the subject. It might be said the present methods have been successful; then why should they not continue to be so? And at what a cost, I would ask, have they been rendered successful hitherto? How many have failed, compared with those who have succeeded? and could not the successful ones

have achieved success in a much shorter time? Those competent authorities who condemn the present modes of teaching Latin, Greek, Mathematics, &c., do not say there have not been produced, under the systems they condemn, great Greek and Latin scholars and eminent Mathematicians; but they say too much time has been expended, owing to the defective methods employed, in acquiring a knowledge of these subjects; and consequently a large number only succeed in acquiring a scanty and unprofitable amount. A reconsideration of our present methods of teaching the NATURAL SCIENCES is at least required, for they were framed for those who studied them as a profession, or as a part of a professional education; this class of students devoted all, or a greater portion of, their time to their acquirement, and those who first cultivated this branch of learning would have a greater natural aptitude, as a rule, for acquiring it than the average student will have when it becomes a branch of general education, and he will have much less time, on that account, to devote to its acquirement than the professional student. But why should a perfect or the best system, which has not been accomplished for any other branch of learning, have been attained for the teaching of Natural Science. There are, I think, reasons (which I will allude to farther on)

be made in teaching Natural Science than in teaching the older branches of learning.*

That the methods adopted for teaching Latin and Greek were imperfect has been attested by such eminent authorities as the late Rev. Dr. J. W. Donaldson, Prof. George Long, Milton, Southey, Professors John Stuart Blackie, D'Arcy Thompson, &c. In 1872, M. Jules Simon, in his capacity of Grand Master of the University and Minister of Public Instruction in France, appealed, in distributing the prizes to the students of the upper forms of the Paris Lycées, to the professors who taught Latin and Greek, *to change their method*, and put it in harmony with the teaching of modern languages—"For in truth it is rather hard," he said, "for students to spend ten years to acquire an utter abhorrence of Latin and Greek."

Southey said: "I was from the age of six to that of twenty learning Greek and Latin, or, to speak more truly, learning nothing else. The little Greek I had, sleepeth, if it be not dead, and can

* The President (M. Bardont) for 1879 of the Annual Congress of the Association for the Advancement of Science, which was held at Montpellier, pointed out in the course of his Inaugural Address that the modes of teaching should follow the development of modern society, and that the old method, in which memory played the principal part, should be abandoned. What was now required was a system of instruction which developed the judgment, and set it on its guard against chimeras, without extinguishing the cultivation of the beautiful. This was the urgent reform, he considered, which secondary instruction needed.

hardly rise without a miracle; and my Latin, though abundant enough for all useful purposes, would be held in great contempt by those people who regard the classics as the scriptures of taste."

Gibbon said: "At the expense of many tears and some blood, I purchased the knowledge of the Latin syntax." And a Biographer of his remarks: "Whether all love of study would have been flogged out of him if he had remained at school, it is difficult to say. But it is not an improbable supposition that this would have happened. The risk was removed by his complete failure of health." The talented Professor of Greek (D'Arcy Thompson) in the Queen's College, Galway, thus alludes to his experience as a schoolboy and as a teacher, in his work, "Day Dreams of a Schoolmaster:" "The day after my entry into this colossal institution (the Grammar School of St. Edward) a Latin grammar was placed in my hands. It was a bulky book of its kind; considering the diminutiveness of the new student (seven and a half years of age at the time) a portentously big book. It was bulky in consequence of its comprehensiveness. It gave all imaginable rules, and all imaginable exceptions. It had providentially stored within it the requisite gear for whatever casualty might befall us. The syntax rules, in the edition presented to me, were, for the first time, rendered mercifully in English; those for gender and quantity remained in the old

Latin, and the Latin was communicated in a hideously discordant rhythm. Over a space of years we went systematically through and through that book, page after page, chapter after chapter. It was all unintelligible, all obscure ; but some spots were rapt in more than ordinary gloom. Our chronic bewilderment was varied from time to time by shooting pains, brought on by some passage or expression unusually indigestible. We read of Creatures, happily few in number, that went about in the *Epicene Gender*. Were they fish, flesh or fowl ? Would the breed be ever extinct ? Under certain desperate circumstances, a participle and a noun together were bound hand and foot, and put into the *Ablative Absolute*. What had they done to be treated in a manner thus peremptory, unreasonable, crochety ? Did they ever get out after being once put in ? Then there were gerunds in Di, Do, and Dum. How they recalled to us that old *Fee, Fi, Fo, Fum*, and the smell of English blood ! And supines in *Um* and *U*. What was the meaning of these cabalistic names ? I did not know then, and I do not know now. And yet I have been behind the scholastic curtain for twelve long years. There was no entire chapter in the book more broken with pitfalls than that, composed in doggrel, which treated of the rules for gender. . . . Many of the words in that puzzling liturgy I have never fallen in with since, though I have

been a student of its dialect for twenty-seven years."

Professor Thompson *had nine years of classical drilling*, and obtained the proud position for a schoolboy of being dubbed Hellenist; yet he states unhesitatingly, that all that he had learnt might very easily indeed have been acquired had he commenced in his thirteenth instead of his eighth year, and had *the system of instruction been natural and easy*, instead of being *unnatural* and *difficult*. This waste of time and impediments in learning did not arise from inefficient masters, but from the system of instruction pursued, for Professor Thompson states the masters were not to be surpassed; the Head Master, like all teachers earnest in their work, was the *fellow-student* rather than the *master* of those he taught. *They taught as they themselves had been taught*; they knew the subjects they had to teach; but they were not Arnolds or Pestalozzis; they had never studied How to Teach? They had neglected to observe that the best system of teaching any subject is that which yields *to the taught* the greatest interest and pleasure, which produces *activity*, not *indolence*; for the healthful exercise of the mind, like the healthful exercise of the limbs, yields pleasure and not pain.

Prince Bismarck has expressed his opinion in favour of teaching the Russian language in preference to teaching Latin and Greek: "When

in the first form at my grammar school I wrote and spoke Latin fairly. I could not do as much now. As to Greek, I have entirely forgotten it. I cannot conceive why Greek should be learnt at all. The practice is probably adhered to because scholars dislike to see that slighted which took them so much time and trouble to acquire. If it is contended that the study of Greek is excellent mental discipline, to learn Russian would be still more so, and at the same time practically useful. Twenty-eight declensions and the innumerable niceties by which the deficiencies of conjugation are made up for are something to exercise the memory. And then, how are the words changed? Frequently nothing but a single letter of the original root remains."*

Professor Max Müller has remarked that, by comparing the structure of Latin, French and English sentences, more was to be gained in one hour than in ten spent in reading the works of classical authors.

The methods employed for teaching Mathematics in schools are considered by competent judges to be imperfect. A Society, composed of eminent mathematicians, was formed some years ago for the

* At the Harvard University, the oldest university in America, they are commencing to teach the Chinese language, for commercial purposes alone; a Chinaman has been appointed the Professor of the language.

purpose of improving the mode of teaching this branch of learning in schools. Messrs. Demogeot and Montucci, in their Report on English Education, begin one of their chapters with the following remarkable words :—"Le trait distinctif de l'enseignement des mathématiques en Angleterre c'est qu'on y fait appel plutôt à la mémoire qu'à l'intelligence de l'élève." In the Report of the Schools Inquiry Commission, the Commissioners state that the Assistant Commissioners generally noticed that the teaching of Mathematics in English schools is rarely satisfactory. . . . . "It seems evident that while the teachers, as a rule, do not take much interest in the subject, in all probability the methods of teaching also want improvement."

The Director of the Royal Naval School, Greenwich (Professor T. Archer Hirst), observes, with reference to Euclid as a text-book of Geometry: "For several years the conviction appears to have been steadily gaining ground, that the admitted imperfections in the teaching of Geometry in English Schools and Colleges are in a great measure traceable to the fact that England, unlike almost every other nation, still adheres to a text-book written upwards of 2,000 years ago, and then probably for a purpose very different from the one to which we applied it. Notwithstanding its many unquestioned and unrivalled merits (indeed, partly because of them), Euclid's Elements cannot,

even by its most ardent admirers, be pronounced to be the best possible introduction to the study of Geometry. . . . . A main object with Euclid appears to have been to show how little need be assumed in Geometry, and how much that is obvious as well as obscure may be demonstrated, and that, too, under difficulties which are never encountered, and in spite of restrictions which are never imposed."

The late Professor Key went so far, before the Schools Inquiry Commission, as to express a wish to get rid of Euclid altogether. He said it was a most illogical book; and Mr. Griffiths, the then Secretary to the British Association, stated before the same Commission that many boys had read six books of Euclid who knew nothing of geometry. Mr. J. M. Wilson, Fellow of St. John's College, Cambridge, in the Preface to his "Elementary Geometry," says: "Euclid's recognized and acknowledged faults as a system of Geometry, and as a specimen of analyzed reasoning, are of slight importance compared with others of greater magnitude. The real objections to Euclid as a text-book are his artificiality, the invariably syllogistic forms of his reasoning, the length of his demonstrations, and his unsuggestiveness. Mr. Wilson, in the same Preface, states that GEOMETRY is taught on several grounds, one of which is, that it forms an excellent subject-matter for continuous

reasoning and clear demonstration. . . . . ALGEBRA fails as a discipline, because it speedily degenerates into a manipulation of symbols.*

Mr. Woolhouse observes, in his "Principles of the Differential Calculus": "It is to be regretted that most of our academical treatises on this, as well as other subjects, abound so much with complex algebraical processes, without the slightest trace of logical reasoning to exercise and improve the intellect. We should bear in mind that the simple execution of analytical operations acquired by dint of practice and experience is a mere common species of labour, often merely mechanical; whilst a distinct apprehension of the specific object and meaning of the operations, and a contemplation of the clearness and beauty of the various arguments employed, constitute the intellectual lore that gratifies and enriches the mind, and stimulates its energies with an ardour after the investigation of truth."

Dr. Whewell forced the University of Cambridge to consider the question, "What is it that we are teaching the undergraduates Mathematics and Physics for?" *The good of education is twofold;* it is made up of the value of the acquirements, and of the intellectual benefit obtained in the

* I would refer those who wish to see the opinions of the

process of acquiring; with the abler men the first, with the inferior ones the second, predominates." Dr. Whewell recommended the old geometrical methods in preference to the analytical methods for the elementary teaching of Mathematics on purely educational grounds. "Dr. Whewell," states Mr. Sedley Taylor, "in a little-read but sound and suggestive book ('Principles of English University Education'), published in 1837, pointed out with remarkable clearness the causes which give to the study of exact science its educational value. One of the most important of these is the distinct and sharply-defined meaning assigned to every term used. When, in a train of reasoning, the mental conceptions corresponding to the terms employed are kept clearly and continuously in view, and the conclusion arrived at springs directly out of the relations which those conceptions bear to each other, we have, according to Dr. Whewell, a process of the highest educational utility. On the contrary, he assigns the lowest value to the kind of reasoning which reaches its conclusion without requiring this steady and unrelaxing grasp of the ideas with which it deals. The distinction may appear, at first sight, somewhat superfluous, since accuracy of conception is the essence of all scientific reasoning. Nevertheless, the nature of the progress made by the mathematical sciences since

This progress is due to the almost exclusive demination of *analysis*. The essence of this powerful and highly developed method of investigation consists in its representing the mental conceptions involved in any inquiry to which it is applied by certain symbols. These symbols are then treated according to fixed rules, entirely independent of the nature of the problem under discussion, and the same whether we are investigating the motion of a planet, the flow of a river, or the tints of a coloured fringe of light. During the process, the meaning of our symbols is of no importance; we may even be unconscious that they possess any meaning at all; and, only when the analytical instrument has performed its task, need we ascertain what our symbols stand for, and translate into mental conceptions the result to which it has conducted us. A scientific inquiry carried on by the aid of the method just described involves, therefore, three steps: the reduction of the data of the problem to a symbolic form; the application of the analytical process; and the return to non-symbolic expression. Only during the first and concluding stages are we directly dealing with the conditions before us; during the second we, as it were, hand these over to a self-acting machine,* which is capable of working them up

* In the manipulation of algebraical processes and symbols the pupil too frequently follows a sort of

into a finished result. On the other hand, in the old geometrical methods used before the invention of the differential calculus, a concrete conception was steadily kept in view from one end of the inquiry to the other. This method, however, though admirable for the clear exposition of known elementary laws, proved inadequate as an instrument of research, or even as a means of demonstration in the higher regions of scientific truth. Accordingly it has for these purposes been completely superseded by modern analysis."

You may ask, and very naturally, what has all that you have quoted with regard to the methods adopted for teaching Latin, Greek, and Mathematics to do with the subject of these Lectures—viz., SCIENTIFIC AND TECHNICAL EDUCATION. My answer is, that it is always stated by *Conservative Educationists*, whenever the question is raised about the introduction into the Educational Curriculum of other branches of learning, how admirably adapted Latin, Greek, and Mathematics are for mental discipline and cultivation, and therefore it would be unwise to interfere with their beneficial

compared to a spectator "who sees linen rags put into a receptacle at one end of a paper-mill, and is told to put one piece after another of machinery in motion, and is then taken to see these same rags passing out from under a roller at the other end of the mill in the form of a smooth breadth of paper."

* Mr. Sadler on "Endowed Competitions at the Univer-

effects by introducing new subjects of study. I have therefore taken the liberty of summoning into Court, as it were, those who are most competent to give an opinion as to how these subjects have hitherto been taught, and I think I have shown by their evidence, that however well these subjects may be adapted for mental discipline and cultivation, they have not at all events been taught in a way to secure that desired result.

I have also another object in view in producing this evidence; I believe that mechanical and not philosophical methods are at present employed in teaching Natural Science, as they have, as you perceive from the eminent authorities I have quoted, been employed to teach the older branches of learning; and my desire is to inform and interest the Educated public, for without their co-operation and assistance the substitution of philosophical, for the mechanical, methods of teaching Natural Science will be long delayed, for the imperfect methods have the prescription of TIME and AUTHORITY on their side, and therefore, unless the public are thoroughly informed on the subject, it may take as long in this Country to abolish them, as it has taken to find out that Euclid is not the proper text-book for teaching Geometry to beginners.

The "Analysis of Sentences," which now forms an essential part of our best English school Gram-

mars, has only been within a comparatively short time introduced; and it is not the production of our own grammarians, but is simply a transcription of the principles developed by Becker in his German Grammar. The publication of Becker's work, Mr. C. P. Mason, Fellow of University College, London, states in the preface to his own Grammar, "may well be regarded as an epoch in the history of Grammatical Science. Its leading doctrines are incontrovertibly sound and philosophical, though the same unqualified praise is by no means to be bestowed on the details of their development."* Mr. Morrell, who was the first to apply Becker's principles in the writing of an English Grammar, states, in the preface to his work: "The method of analysis I have adopted is that which has been applied to the German language with so much advantage by Dr. Carl Ferdinand Becker. Since the publication of his celebrated Grammar in Germany, every enlightened teacher in that country has seen the advantage of the proceeding herein inculcated."

Formerly, boys in our Classical schools were not

* "In one of the grammatical tablets preserved in the British Museum, King Assurbanipal declares—'I caused these tablets of instruction to be written for the promotion of learning, which no king before me had ever done;' undeniably the first reference to elementary instruction published in ancient times, published by a Government or Monarch dating upwards of two thousand five hundred years back."—*Daily Telegraph*.

taught the grammar of their native language, but had to learn it through the Latin and Greek Grammars. This was considered by the Classical teachers of the day as the best method of teaching English grammar; this view is not held now by our best teachers. The Rev. Dr. Abbott, the Head Master of the City of London School, states, in the preface to his work, "How to Write Clearly," that "boys who are studying Latin and Greek stand in special need of help to enable them to write a long English sentence clearly. The periods of Thucydides and Cicero are not easily rendered into our idiom without some knowledge of the links that connect an English sentence.

"There is scarcely any better training, rhetorical as well as logical, than the task of construing Thucydides into genuine English; but the flat, vague, long-winded Greek-English and Latin-English imposture that is often tolerated in our examinations, and is allowed to pass current for genuine English, diminishes instead of increasing the power that our pupils should possess over their native language. By getting marks at school and college for construing good Greek and Latin into bad English, our pupils systematically unlearn what they may have been allowed to pick up from Milton and from Shakespeare."

According to Mr. Herbert Spencer and other eminent authorities, not only our *school* histories,

but also *those for adults*, have, until recently, been a mere *tissue* of *names*, *dates*, and *dead unmeaning events*.

Mr. Carlyle, in his inaugural address as Lord Rector of the University of Edinburgh, thus alludes to History-books:—"Upon the whole, I do not think that, in general, out of common History-books, you will ever get into the real history of this country, or anything particular which it would beseem you to know. You may read very ingenious and very clever books by men whom it would be the height of insolence in me to do any other than express my respect for. But their position is essentially sceptical. Man is unhappily in that condition, that he will make only a temporary explanation of anything, and you will not be able, if you are like the man, to understand how this island came to be what it is. You will not find it recorded in books. You will find recorded in books a jumble of tumults, disastrous ineptitudes, and all that kind of thing. But to get what you want you will have to look into side sources, and inquire in all directions."

If School Histories were a mere tissue of names, dates, &c., Geography, as it was taught in my schoolboy days, was even more so; but I must pass on.*

* In examining a History of England the other day, which a young boy was taking to school with him as one of his school-

Jean Paul Friederich Richter in his Autobiography thus alludes to the *Mechanical system* of teaching:—"Yes, this mental self-nourishing of children is capable of such extension that I myself would undertake to superintend, through the *letter-post*, a whole school in North America, or fifty days' journey distant in the Old World, merely by writing to my school-children what they were to learn each day, and keeping some or other *insignificant* person there to whom they should *repeat* it; while I myself would enjoy the consciousness of *the beautiful remembrances* they would have of the lessons they had learned by *rote!*" What Richter said might be done by mechanical modes of teaching is really now employed; teaching through the post appears to be now pretty extensively carried on. Advertisements are frequently appearing in the Press,

books, I was not surprised that the boy was going unwillingly to school, for anything more uninviting and indigestible I could not conceive; all that would have been of interest to the little fellow had been omitted, and the dry bones of names and dates were all that was given. It occurred to me that, if instead of these so-called Histories, books were written describing interesting historical events which have taken place in different parts of the kingdom, and the young of both sexes commenced the study of history by reading one of these books describing the historical events which had taken place in the neighbourhood where the school was situated, it would lead them to take an interest in the events which had happened in other parts of the kingdom and in other countries.

I would commence the teaching of Geography in a similar manner, by commencing with the geography of the neighbourhood

offering to prepare young men through the post for University Examinations, for Army Examinations, for the Intermediate Schools Examinations, Ireland, for Pharmaceutical Examinations, &c.; instruction so given can be nothing else but pure and unadulterated cram.

Before entering upon the *merits* and *demerits* of the methods generally employed for teaching Chemistry, I will quote some AUTHORITIES to show that I am not singular in thinking the methods employed in teaching the Inductive Sciences admit of improvement.

The late Professor Henfrey, in the Introduction to his work on Botany, states that "he quite concurs with the opinion expressed by the distinguished Authors of the 'Flora Indica,' who believe that disservice is done to the cause of Botany by occupying the attention of the students in the first instance with the abstract parts of the Science. To direct," he says, "the attention of the students to a series of isolated facts and abstract propositions relating to the elementary anatomy of plants, is to cause him to charge his memory or his note-book with materials in which he can but take little interest from his incapacity to perceive their value or application. Some of the most important questions of Physiology are as yet in no very advanced state, and the conflicting evidence of many of these questions cannot be properly

appreciated without an extensive knowledge of plants. But if we endeavour to seize the floating conceptions furnished by common experience, and to fix and define them by a course of *exact practical observation* of the more accessible characters of plants, showing the relations of these as they occur in different divisions of the vegetable kingdom, we place the student in a position which enables him to proceed at once with an inquiry into the peculiarities of the plants he meets with, and in this way to acquire a fund of practical knowledge, which is not only absolutely requisite before entering on abstract inquiries, but it is especially calculated to secure his permanent interest in the study."

Of the three Sciences of classification, Botany is not only the most complete in its method (Mineralogy and Zoology having greater difficulties to contend with), but the plants, which are to be met with in the country in which the student resides are, as a rule, more easily obtained than the specimens belonging to the other two sciences; yet with these advantages, and the pleasure all take in flowers, the success that might have been expected has not been obtained in teaching it, owing to the defective methods adopted. Instead of commencing with those parts of a plant which are known to some extent by all, the teacher

to be *discovered, observed,* and *described by the learner,* instead of being, as they generally are, *described, by the teacher,* would require for their examination a greater cultivation of the perceptive faculties than the learner can have at the time acquired, and they are not the most suitable for making the learner COMPARE, DISTINGUISH, JUDGE. If the late Professor Henslow had taught Botany to his VILLAGE CLASS as it is taught in most of our Colleges and Medical Schools, *he would have had no class to teach;* and Sir Joseph Hooker has certified as to the botanical knowledge of these village pupils, who belonged to the labouring class; for he stated before the English Public Schools Commission that in conducting the botanical examinations of Medical Men for the Army, which he had done for several years, and for the East India Company's service, which he had conducted for about seven years, the questions which he was in the habit of putting, and which were not answered by the majority of the candidates, were what would have been answered by the children in Professor Henslow's village school. He further added that, in most Medical Schools, the whole sum and substance of Botanical Science is crammed into a few weeks' lectures, and the men leave the class without having acquired an accurate knowledge of the *merest* elements of the science.

science, do not obtain a knowledge of the science as a science; they only acquire by the aid of the memory some stray and disconnected facts.

With regard to the study of Geology, the late Professor Joseph Beete Jukes stated, in his address as President of the Geological Section of the British Association, that "*one day in the field* was worth *all the lectures* and *all the museums put together*;" and Professor Archibald Geikie, in his "Outlines of Field Geology," states "that *a few days* of intelligently guided observation *in the field* are worth *far more* to a pupil than *many weeks of lectures* and *reading*." Yet Geology is taught mainly, if not entirely, in the Lecture Room. Why should a method of instruction be pursued which is so faulty? How can a student learn to be a good geologist by merely listening to lectures on the science in the Class-room? He cannot learn in the Class-room how to conduct the preliminary geological examinations in the field, to trace the geological boundary-lines, unravel the geological structure—in short, to *examine* and *survey* a country *geologically*, and then to insert the information he has obtained in his note-book, and finally construct the necessary sections and maps of the country he has surveyed. The substitution of *practical* for *theoretical* instruction would necessitate the teacher having a practical knowledge of the subject himself; "but," says Professor Geikie,

"we seldom hear of such practical instruction, *mainly because* the teachers never received it, and have not had time, inclination, or opportunity to develop it for themselves."

Those of my readers who have not been behind the scholastic curtain may be surprised to learn from such an excellent authority as Professor Geikie that there are teachers of Geology who are not geologists; but the lack of knowledge in the teacher is not confined to those who profess to teach Geology—it extends to other branches of science; hence the frequent substitution of lectures (*talk*) for practical work. A man may lecture on a science without his hearers discovering he is an IMPOSTOR; but if he attempts practical instruction in the *laboratory* or *field*, his students soon find out to what extent he is acquainted with it.

The late Professor Edward Forbes observed, when he lectured on Botany in King's College one session a gentleman invariably in the Lecture Theatre when he entered, and that he was also most assiduous in copying the lectures. This marked punctuality and attention aroused Forbes's curiosity; he therefore set to work to find out who this exemplary student was. He at length ascertained that he was a lecturer on Botany at one of the other London Medical Schools, and that he delivered, a little later on in the day, at the

lecture Forbes had given earlier in the day at King's College.

Professor Huxley, in a lecture he delivered to a class of Teachers on the study of Zoology, said: "Let me entreat you to remember my last words. Addressing myself to you as Teachers, I would say *mere book learning* in Physical Science is a sham and a delusion; what you teach, unless you wish to be impostors, that you must first know. A real knowledge in science means *personal acquaintance* with the facts, be they few or many. With regard to the teaching of Zoology," he said, "I am well aware that there are great difficulties in the way of effectual Zoological demonstrations. The dissection of animals is not altogether pleasant, and requires much time; nor is it easy to secure an adequate supply of the needful specimens. The botanist has here a great advantage; his specimens are easily obtained, are clean and wholesome, and can be dissected in a private house as well as anywhere else. . . . . But, be it difficult or be it easy, if Zoological Science is to be properly studied, demonstration, and consequently dissection, must be had. Without it no man can have a really sound knowledge of animal organization."

The course generally pursued in teaching Zoology, and, as we have shown previously, in teaching Botany, is the very reverse of the plan recom-

time is given to dissection; but a classification is laid down, even in short courses of lectures for mere beginners, which carries out the extremest minutiæ of classification, so that to the student, who has generally other subjects to study, these sciences become a mere tissue of names. The earnest students are disheartened, and become *mentally* sick, for they find it must be mere *cram*; a spirit of indifferentism naturally springs up, owing to the *mental torture* to which they are subjected by this unnatural mode of teaching.*

* Professor Henslow was Professor of Botany at Cambridge; according to Dr. Hooker, his village class was the lowest possible—it consisted of labourers' children in a remote part of Suffolk. It was entirely a voluntary system: the class was limited to forty-two; it consisted chiefly of girls; their ages varied from about eight years old to about fourteen or fifteen. Before they were enrolled in the class, they were required to spell a few elementary botanical terms, including some of the most difficult to spell, and those that were the most essential to begin with. Professor Henslow being a true educationist, did not unnecessarily introduce terms derived from Greek and Latin when English ones would do equally well. He did not substitute diagrams or artificial flowers for the actual objects themselves. His mode of teaching was *practical*; he made it an *objective* study. The children collected the plants themselves, and they were taught to know them; to give their proper names to the parts; to indicate the relations of the parts to one another, and to find out the relation of one plant to another by the knowledge thus obtained. This *real* and *natural* mode of teaching of course rendered the children exceedingly fond of it, consequently there was no difficulty in teaching it; the children were rendered more intelligent than those of other parishes, and Professor Henslow and the school inspectors attributed it to this study. He considered Botany was the most important agent that could be employed for cultivating children's faculties of observation, and strengthening their reasoning powers.

If Teachers were to substitute more of *reality* and less of *artificiality* in their teaching, there would be more attentive and painstaking students. Professor John Stuart Blackie, in his Lectures on the Method of Studying and Teaching Languages, observes :—"A classical teacher, when he can afford it, ought to travel, and see the present state of those countries of which he has to speak so much. 'When I was at Babylon and stood upon the Tower of Belus'—dropped accidentally from a professorial mouth—will cause a

subject can be departed from, and what pitfalls and indigestible matter can be introduced into a delightful study, I append an extract of a review of a small book on Botany, price about eighteenpence, which appeared in the *Quarterly Journal of Science* for 1879 :—

"We regret to see a constant tendency on the part of the author to use terms derived from Greek and Latin, most of them neologisms, when English ones would serve just as well. What possible end can it serve to call the stem of a plant a *caulome*, the leaf a *phyllome*, and its hairs *trichomes*, and that, too, without giving the pupil the least clue to the derivation of these and a hundred other similar words? We must really warn teachers against using a book for any class of schoolboys whose chief end seems to be to cram their minds with such facts as these—that 'imperfect self-fertilizing flowers are kleistogamous;' that 'flowers fertilized by the agency of birds are called ornithophilous;' or that in 'sympodial dichotomies the sympodium consists either of the fork-branches of the same side, right or left, the bostrychoid (helicoid) dichotomy, as seen in the leaf of *Adiantum pedatum*; or the branches are alternately right and left, the cicinnal (scorpioid) dichotomy of many of the Selaginellas.' We thought that pedantic cramming was being speedily eradicated from our educational system, but the noxious plant seems still to be flourishing."

pricking in the heels of the dullest boy, and make him limp through his Curtius for the moment with a less painful feeling of lameness. *The young have a strong appetite for reality; and the teacher who does not make use of that appetite is not wise.*"

Before passing away from the consideration of these sciences, Botany and Zoology, I would recommend those who are beginning to study the former science to search for and study with their Flora and the few instruments required for out-door work—the *wild flowers* in the field, rather than in Botanic gardens; for the advantages to be derived from searching for and studying flowers in their *natural state* is great indeed, compared with what is gained by seeing them grow under artificial conditions. The student by studying them in the field learns for himself the habitats of the plants he discovers and studies; but he will acquire a great deal more knowledge than this, for he will soon discover, as he rambles in the *country* in search of flowers, that although "he has eyes, he sees not," for where the more trained botanist discovers flowers, he sees none, and it will only be after his perceptive faculties have been *trained in this direction* that he will discover the more rare flowers; until then he will only discover those that are growing almost as plentiful as daisies or buttercups. It is the same with regard to all the other senses. The NATURALIST, for instance, will

hear the notes of many birds in the woods where the untrained ear will hear only a few; in like manner the uneducated workman in a chemical factory by the training of the eye will recognize the completion of a process where the untrained sight observes little or no change.*

The Lecture-taught class-room Student of Geology or Mineralogy will find, no doubt to his dismay and disgust, that the uneducated Fossil collector, or the uneducated Miner, will discover Fossils or Minerals which he will fail to do under the same conditions. "Ladies," states Professor Cooke in his Essay upon Scientific Culture, "will scout the idea that a brooch of cut-glass is as ornamental as one of diamond; and yet I venture to assert that there is not one person in fifty, at least of those who have not made a study of the subject, who can tell the difference between the two. The external appearance depends simply on what we call lustre. The lustre of glass is *vitreous*, that of the diamond *adamantine*, and I know of no other distinction which it is more difficult for students to recognize than this."

* A fireman in London and an Indian in the prairie can smell smoke when nobody else is aware of it; in like manner, the miller who employs water as the motive power for his mill will, as he listens to the run of the water when he is sitting by the fireside, tell whether the stream is deep or threatening to go dry; and a shepherd is perhaps the best able to form an estimate of the number of persons present in a crowd.

A gentleman, a friend of mine, who had studied Geology and Mining in one of our Technical Colleges, and who had obtained the Diploma and all the other certificates affirming his proficiency in these subjects, has furnished me with the following most interesting and instructive description of what he experienced when he went to put what he considered his knowledge of the subjects into practice in the Mine itself. He had been taught at the Institution Geology and Mining, not in the Field and Mine, but in the Class-room by Diagrams.

"Never shall I forget my utter bewilderment upon first going inside a Mine, and putting my theoretic knowledge to the test. 'Where is the lode?' I asked, when in fact I was in the middle of it! Until then I thought that I knew a great deal about Mining, and had all the DIAGRAMS—black and white, and sharply defined—pat in my head; but *here* (in the Mine) nothing but darkness, dirt, and wet! And, indeed, it took me weeks of daily visits to know where I was, and to learn how to see things as they really are, instead of as my regular DIAGRAMS would have them.*

* Professor Bain, in his work "Education as a Science," has the following excellent remarks on the difference between teaching by Diagrams—as, for instance, Diagrams of, Geological sections, or Plants—and the *actual objects*:—"Professor Huxley seems to hold that zoology cannot be learnt with any degree of sufficiency unless the student practise dissection. In support of this position there are strong reasons. In the first place, the impression made on the mind by the actual objects, as *seen, handled*, and *operated* upon, is

"The conclusion that I have arrived at, from the experience of myself and of others, is that it is almost as *sensible* to attempt to learn *Mining* away from the *Mines*, as it would be to try to acquire a knowledge of *Seafaring* without going to sea in ships, or of *Doctoring* without visiting the sick."

The following occurred to a Diagram-taught student of Geology:—He had to make a Survey, and after he had been some time down in the country a Geological map of a totally different Geological district to the one he was in was sent him, to show him how to inscribe the results he had obtained by his Survey on a map of the district he was in. He copied the map sent, and forwarded the copy as the result of the Survey of the country he had made. This is not to be wondered at, when we consider the way Geology is usually taught.

Mr. Herbert Spencer observes—"Everywhere throughout creation we find faculties developed through the performance of those functions which it is their object to perform; not through the

far beyond the efficacy of words or description. And not only is it greater, but it is more faithful to the fact. While diagrams have a special value in bringing out links of connection that are disguised in the actual objects, they never can show the things exactly as they appear to our senses; and this full and precise conception of actuality is the most desirable form of knowledge; it is the truth, the whole truth, and nothing but the truth. *Moreover, it enables the student to exercise a free and independent judgment*

performance of artificial exercises devised to fit them for those functions. The Red Indian acquires the swiftness and agility which make him a successful hunter, by the actual pursuit of animals; and through the miscellaneous activities of his life he gains a better balance of physical powers than gymnastics ever give. That skill in tracking enemies and prey, which he has reached after long practice, implies a subtlety of perception far exceeding anything produced by artificial training. And similarly in all cases. From the Bushman, whose eye, habitually employed in identifying distant objects that are to be pursued or fled from, has acquired a telescopic range, to the accountant, whose daily practice enables him to add up several columns of figures simultaneously; we find that the highest power of a faculty results from the discharge of those duties which the conditions of life require it to discharge."

For the sake of rendering what I have to say on the teaching of Chemistry as applicable as possible to all other branches of Natural Science, I have arranged the matter under the following heads:—The Educator, some of the essential qualifications he ought to possess; what he has to guard against in his students. The organization of science schools. The methods best adapted for teaching the science, and its applications.

No one is so insane as to suppose that every

educated person must, by reason of his education, be a Poet or an Orator. It is well known that many well-educated men are unable to address an audience without preparatory training, and many even then fail to acquire the power to speak with effect, or be able to confer pleasure on their hearers. Yet it is all but a prevalent belief in England that any one can act as a teacher who has a knowledge of the subject to be taught. No natural aptitude or training for the task has been deemed necessary. Hence the tutorial office in our Grammar Schools has been generally occupied by Clergymen, many of whom have no natural aptitude for this most difficult and arduous Profession; and many frequently undertake it as a makeshift until they have received some appointment in the Church.*

* "*Nascitur, non fit*, may be said as truly of the schoolmaster as of the poet. The popular, but mistaken idea is, that any young man, who at the age of twenty-one is well enough educated for a learned profession, but lacks the means or spirit to push his way in the world of Law or Medicine, may subside into a teacher of the Classics. Many young Englishmen think so themselves, and take clerical orders at the time of entering the despised profession, that they may escape from it, if on any *white day a vicarage* should fall from the clouds. These are they that are not born schoolmasters, but made schoolmasters of men. In the matter of education, Scotland is, in many points, in advance of her southern neighbour. The middle-class preparatory schools of Dunedin are unapproachably superior to anything of the kind—if there be anything of the kind—in England. . . . . In Scotland, also, the profession of teaching, though not sufficiently honoured from a social point of view, is rightly considered as *specific*, and calling for *specific qualifications*. When Adam and Carson of our High School, Melvin of Aberdeen, and

"The result has been what might naturally have been expected, when one of the most *intricate problems* has been undertaken by those who have given scarcely a thought to the principles on which its solution depends. For shoe-making or house-building, for the management of a ship or a locomotive engine, a long apprenticeship is needful. Is it, then, that the unfolding of the human mind is so comparatively simple a process that any one may superintend and regulate it with no preparation ?" Although it is tardily beginning to be admitted that the mere acquisition of knowledge does not of itself make a good teacher, and that some professional training is required as in other professions, there is no training college in England for the training of masters for the middle and higher schools. Scotland is in advance of England and Ireland in this respect. Chairs of Pedagogy have been established in the University of Edinburgh and in that of St. Andrews. The office of teaching does not even form a distinct profession in England; it does in Germany.

The Bishop of Manchester, on October 24th, 1878, in distributing the prizes at the Bath centre

to their craft, they left no plank behind them for re-crossing at a favourable opportunity to ease or affluence in an extraneous calling. They put their hands to the plough, these simple men; and there was no looking back. They devoted themselves to the business of classical instruction as single-heartedly as did the Apostles to the dissemination of Christian doctrine."—*Day Dreams*

of the Oxford local examinations, observed in reference to middle-class education, that if the middle classes of England wished to maintain their position, it was time they bestirred themselves. In proof of this he mentioned that for the Scholarships at the Manchester Grammar School 96 out of 145 Candidates came up from elementary schools, and 14 out of 24 Scholarships were given to these elementary Scholars. The Bishop did not attempt any explanation of the fact—I will volunteer one which I believe to be the true one: it is owing to the fact that the teachers in the elementary schools receive some training How to Teach; those in the middle as well as those in the higher class schools do not.*

* What a change has taken place in the condition of the Primary Schools since the first public grant for primary education was applied for and passed in the House of Commons in 1847! I will give one or two extracts from Lord Macaulay's great speech on education in the House on that occasion to show the great improvement which has taken place in the Educators and Education in the Primary Schools since that time; much, nevertheless, still remains to be accomplished. Mr. S. Tremenhere had made a report to a department of the State on the condition of that part of Monmouthshire which was inhabited by a population chiefly employed in mining. "He found that in this district, towards the close of 1839, out of eleven thousand children who were of an age to attend school, eight thousand never went to any school at all, and that most of the remaining three thousand might almost as well have gone to no school as to the squalid hovels in which men who ought themselves to have been learners pretended to teach. In general these men had only one qualification for their employment, and that was their utter unfitness for every other employment.

Although all has been changed with respect to the Primary Schools—disabled Miners and broken-down hucksters no longer being allowed to teach the children of the lower classes, the State now providing them with Schoolmasters who have been educated and trained for the office—yet for the education of their children the middle class are still mainly left to what is termed "the natural operations of supply and demand." Those who have failed in every other adventure in life can as a last resource set up a school or academy,

all was stench and noise and confusion. Now and then the clamour of the boys was silenced for two minutes by the furious clamour of the master; but it soon broke out again. The instruction given was of the lowest kind. Not one school in ten was provided with a single map. This is the way you suffered the minds of a great population to be formed. And now for the effects of your negligence. The barbarian inhabitants of this region rise in an insane rebellion against the Government. They come pouring down their valleys to Newport. They fire on the Queen's troops. They wound a magistrate. The soldiers fire in return; and too many of these wretched men pay with their lives the penalty of their crime. But is the crime theirs alone? Look at the charges of the judges, at the resolutions of the grand juries, at the reports of public officers, at the reports of voluntary associations. All tell the same sad and ignominious story. Take the reports of the Inspectors of Prisons. In the House of Correction at Hertford, of seven hundred prisoners one-half could not read at all; only eight could read and write well. Of eight thousand prisoners who had passed through Maidstone Gaol only fifty could read and write well. In Coldbath Fields Prison the proportion that could read and write well seems to have been still smaller. Turn from the registers of prisoners to the registers of marriages. You will find that about a hundred and thirty thousand couples were married in the year 1844. More

and become the instructors of the children of the middle class; and they can engage as teachers to assist them persons as incompetent in every respect for the office as they are themselves—their sole plan of carrying on the so-called education they give is the repeating by rote system and *sticking* to books.

A Manufacturer would not entrust his steam engine to the care of one who knew nothing about machinery; yet how many middle-class parents submit the finest mechanism on earth—a mechanism

than forty thousand of the bridegrooms and more than sixty thousand of the brides did not sign their names, but made their marks. Nearly one-third of the men and nearly one-half of the women, who are in the prime of life, who are to be the parents of the Englishmen of the next generation, who are to bear a chief part in forming the minds of the Englishmen of the next generation, cannot write their own names. Remember, too, that, though people who cannot write their own names must be grossly ignorant, people may write their own names and yet have very little knowledge. Tens of thousands who were able to write their names had in all probability received only the wretched education of a common day-school. We know what such a school too often is—a room crusted with filth, without light, without air; with a heap of fuel in one corner and a brood of chickens in another; the only machinery of instruction a dog-eared spelling-book and a broken slate; the master the refuse of all other callings, discarded footmen, ruined pedlars, men who cannot work a sum in rule of three, men who cannot write a common letter without blunders, men who do not know whether the earth is a sphere or a cube, men who do not know whether Jerusalem is in Asia or America. And to such men, men to whom none of us would entrust the key of his cellar, we have entrusted the mind of the rising generation, and, with the mind of the rising generation, the freedom, the

so fine that, once seriously disabled, no human engineer can repair—their children's brains to those who have neither knowledge, sympathy, nor training for the task.

Mr. Matthew Arnold observes in his "French Eton"—"In secondary education *the impotence* of the principle of supply and demand is as signal as in elementary education. The mass of mankind know good butter from bad, and tainted meat from fresh; and the principle of supply and demand may, perhaps, be relied on to give us sound meat and butter. But the mass of mankind do not so well know what distinguishes good teaching and training from bad; they do not here know what they ought to demand, and, therefore, the demand cannot be relied on to give us the right supply. Even if they knew what they ought to demand, they have no sufficient means of testing whether or no this is really supplied to them. *Securities*, therefore, are needed. The great public schools of England offer securities by their very publicity; by their wealth, importance, and connections, which attract general attention to them; by their old reputation, which they cannot forfeit without disgrace and danger." The upper and lower classes are not only provided with securities, but also with material aid; the middle class are left unprovided. Dr. L. Wiese believes that the clearness of judgment, which the English display

in their public and private affairs, is most frequently wanting in selecting a place for the instruction or education of their children.

Not only must a teacher, who is worthy to be called one, have great intellectual sympathy with those he instructs—he must have more than this; he must have such a love for humanity, that he will be content to allow all his intellectual exertions to go forth to the world through his students. If he possesses only the former qualification, he will devote himself, even when pecuniary matters do not affect the question, to those who have the greatest aptitude for the subject he teaches, whilst he will neglect those who are inferior in mental power; but if he possesses a great love for humanity, he will not neglect the inferior, whilst he will do full justice to those of superior capacity. The majority of boys and young men require for the successful prosecution of their studies such sympathy that the teacher will be to them as a father or an elder brother, who will rejoice with them in their intellectual victories, and will afford them every encouragement and assistance in their difficulties.

Although the musical faculty seemed intuitive in Mozart, he required so much sympathy in his musical efforts that, it is said, he could neither play nor compose to his own satisfaction, without the consciousness of being enjoyed and appreciated.

It was the same with Shelley; there are indeed few, even when they have reached manhood, who do not require sympathy in their intellectual efforts. Shelley, in a letter to Leigh Hunt, dated January 25, 1822, states: "I write little now; it is impossible to compose except under the strong excitement of an assurance of finding sympathy in what you write." During Shelley's schoolboy days he thus describes the want of sympathy shown him by his Teachers and school-fellows :—

Thoughts of great deeds were mine, dear Friend, when first
The clouds which wrap this world from youth did pass.
I do remember well the hour which burst
My spirit's sleep: a fresh May-dawn it was,
When I walked forth upon the glittering grass,
And wept, I knew not why; until there rose
From the near schoolroom, voices, that, alas!
Were but one echo from a world of woes—
The harsh and grating strife of tyrants and of foes.

And then I clasped my hands and looked around—
—But none was near to mock my streaming eyes,
Which poured their warm drops on the sunny ground—
So without shame I spake :—"I will be wise,
And just, and free, and mild, if in me lies
Such power, for I am weary to behold
The selfish and the strong still tyrannize
Without reproach or check." I then controlled
My tears, my heart grew calm, and I was meek and bold.

And from that hour did I with earnest thought
Heap knowledge from forbidden mines of lore,
Yet nothing that my tyrants knew or taught
I cared to learn, but from that secret store

Wrought linked armour for my soul, before
It might walk forth to war among mankind.
Thus power and hope were strengthened more and more
Within me, till there came upon my mind
A sense of loneliness, a thirst with which I pined.

But you need not travel far for an example of the sufferings a highly intellectual student may have to undergo by coming under the dominion of an unsympathizing teacher; in passing that ancient seat of learning in College Green* you will have noticed the beautiful statue to the memory of Oliver Goldsmith, whose name and fame will last as long as the language in which he wrote his immortal works. How did he appreciate his Instructors? He advises his brother Henry, the Clergyman, not to send his son to the College in the following language:—"If he has ambition, strong passions, and an exquisite sensibility of contempt, do not send him there, unless you have no other trade for him except your own."

Few great men ever attribute any of their future success to those who taught them; I consider this to be due to want of sympathy and appreciation on the part of the Teacher. "To the University of Oxford," Gibbon says, "I acknowledge no obligation, and she will as readily renounce me for a son as I am willing to disclaim

her for a mother. I spent fourteen months at Magdalen College; they proved the most idle and unprofitable of my whole life." The reader, states his biographer, will pronounce between the School and the Scholar.

Burns, who certainly had his share of trouble, appears to have met with in young Murdoch a sympathizing teacher. Burns's father combined with four of his neighbours to hire young Murdoch, who boarded with them, and taught their children for a small salary; and Murdoch has left an interesting description of two of his pupils, Gilbert and Robert Burns. This mode of paying, or hiring as it was termed, teachers, appears not to have been uncommon. When I visited Wast Water, one of the Lake districts in Cumberland, some years ago, I learned that the inhabitants of that primitive spot paid their schoolmaster in a similar manner; each parent who sent him a child to teach gave him board and lodging for a certain number of weeks in the year—he had no domicile of his own; in addition, they gave him a few pounds as pocket-money.

Educational Institutions where, to employ an expression of the late Prime Minister of England, Lord Beaconsfield, "it is always machinery, and never sympathy, which is employed in the government of the taught, must fail to accomplish the

substituted and employed for incentives and encouragements."

Mr. Latham states in his work on Examinations: "The casts of mind required for a man of Science and a Teacher, though sometimes combined, are in one respect different; *sympathy with other minds is not essential for the former—with the latter it is all in all.*"

Dr. Leonard Schmitz, in the preface to the English edition of Dr. Wiese's work, thus alludes to the qualification a teacher ought to possess:—"There are a few points which Dr. Wiese, in common with all true friends of education, would wish to see reformed, and I venture to draw attention to them here, because upon them depends the success of all our other reforms. First, there ought to be a proper method of ascertaining the qualifications of a person before he is allowed to undertake the functions of a teacher. Hitherto the possession of a certain amount of knowledge has been thought sufficient, and the degree of B.A. or M.A. is generally considered satisfactory evidence of a man's possessing qualifications necessary to undertake the education of the young in our great Public Schools. But there is no lack of examples to show that a man may possess any amount of learning or knowledge, and yet be a very indifferent teacher. In addition to

qualities; he must have the power of communicating knowledge in a clear and attractive manner; he must have sympathy with the young in order to be able effectively to guide their actions and inclinations in the right way; he must be enthusiastic in his profession, and not regard its duties, as is too often the case, as mere drudgery; and lastly, he must be able to inspire his pupils with a love for their studies, and for everything that is good and noble. It is obvious that these qualities cannot be discovered by a mere examination for a degree. A second defect to which Dr. Wiese directs our attention is our present system of examinations, which has produced that peculiar species of industry called 'cramming' or 'coaching,' than which nothing could be more dangerous to the interests of true education."

More aptitude is required for philosophical than for mechanical methods of teaching; one of our greatest authorities on Mental Science, Mr. Herbert Spencer, in his work on Education, observes with respect to the two methods: "The success of every appliance depends mainly upon the intelligence with which it is used. It is a trite remark, that having the choicest tools, an unskilful artisan will botch his work; and bad teachers will fail even with the best methods. Indeed the goodness of the method becomes in such cases a cause of failure; as to continue the

disciplined hands a source of imperfection in results. A simple, unchanging, almost mechanical routine of tuition, may be carried out by the commonest intellects, with such small beneficial effects as it is capable of producing; but a complete system—a system as heterogeneous in its appliances as the mind in its faculties—a system proposing a special means for each special end, demands for its right employment powers such as few teachers possess. The mistress of a dame school can hear spelling lessons; and any hedge-schoolmaster can drill boys in the multiplication table. But to teach spelling rightly by using the powers of the letters instead of their names, or to instruct in numerical combinations by experimental synthesis, a modicum of understanding is needful; and to pursue a like rational course throughout the entire range of studies, asks an amount of judgment, of invention, intellectual sympathy, of analytical faculty, which we shall never see applied to it *while the tutorial office is held in such small esteem.* True education is practicable only by a true philosopher. Judge, then, what prospect a philosophical method now has of being acted out; knowing so little as we do of psychology, and ignorant as our teachers are of that little, what chance has a system which requires psychology for its basis ?"*

* "My Teachers, says he, were hide-bound Pedants, without

In Germany education has long since assumed the shape and dimensions of a science, and the prevalence of special psychological theories has exercised an immense influence on educational systems. That little attention is given to the study of psychology by teachers in the United Kingdom is proved, I think, by the few books that are published on the subject; and those

and quarterly account-books. Innumerable dead Vocables (no dead Language, for they themselves knew no Language) they crammed into us, and called it fostering the growth of Mind. How can an inanimate, mechanical Gerund-grinder, the like of whom will, in a subsequent century, be manufactured at Nürnberg out of wood and leather, foster the growth of anything; much more of Mind, which grows, not like a vegetable (by having its roots littered with etymological compost), but like a Spirit, by mysterious contact of Spirit; Thought kindling itself at the fire of living Thought? How shall *he* give kindling in whose own inward man there is no live coal, but all is burnt-out to a dead grammatical cinder? The Hinterschlag Professors knew syntax enough; and of the human soul thus much: that it had a faculty called Memory, and could be acted-on through the muscular integuments by appliance of birch-rods.

"Alas, so it is everywhere, so will it ever be; till the Hodman is discharged, or reduced to hodbearing; and an Architect is hired, and on all hands fitly encouraged; till communities and individuals discover, not without surprise, that fashioning the souls of a generation by knowledge can rank on a level with blowing their bodies to pieces by gunpowder; that with Generals and Fieldmarshals for killing, there should be world-honoured Dignitaries, and were it possible, true God-ordained Priests, for teaching. But as yet, though the Soldier wears openly, and even parades, his butchering-tool, nowhere, far as I have travelled, did the Schoolmaster make show of his instructing-tool; nay, were he to walk abroad with birch girt on thigh, as if he therefrom expected honour, would there not, among the idler class, perhaps

that are published appear to have but a scanty sale. Those who intend to teach Natural Science ought, I think, to give more than usual attention to psychology, as the study of matter appears to me rather to hinder than aid its votaries in the study of mind.

They are beginning to find out in Germany that they must make some concessions to "humanism in their Technical and Trade Schools, for the natural and technical sciences deal solely with the external world. Man as a thinking and feeling creature—his religion, morality, poetry, philosophy, and history—is excluded from their investigations. A harmonious development of mind and heart can, therefore, never be attained by the study of the natural sciences alone. It is not, says Mr. Wilson of Rugby, one of the ablest and most experienced teachers of Natural Science, simply *false* that there is an inhumanity about science. Constant dealing with Nature, and the exercise of the intellect alone, as contrasted with humanity —the exercise of the moral feelings—unquestionably tends to exclude men from the highest thoughts."*

* "The increasing specialization of all employments; the division of mankind into innumerable small fractions, each engrossed by an extremely minute fragment of the business of society, is not without inconveniences, as well moral as intellectual, which, if they could not be remedied, would be a serious abatement from the benefits of advanced civilization. The interests of the whole—the

Young men in college ought to learn, in addition to their studies, How to Command as well as How to Obey; for those who intend to be owners or managers in industrial establishments this is almost as important as book learning. This is always claimed as one of the great advantages of our older Universities; the University being the world in miniature, a young man learns there how to act in the larger world. Education is, or ought to be, according to our present Prime Minister, Mr. Gladstone, "man making." Captain Hosier in his work on the Franco-Prussian War remarks, that the education of the French officers does not seem calculated to create habits of command. A large number are trained, he states, in

bearings of things on the ends of the social union—are less and less present to the minds of men who have so contracted a sphere of activity. The insignificant detail which forms their whole occupation—the infinitely minute wheel they help to turn in the machinery of society—does not arouse or gratify any feeling of public spirit, or unity with their fellow-men. Their work is a mere tribute to physical necessity, not the glad performance of a social office. This lowering effect of the extreme division of labour *tells most of all* on those who are set up as the *lights* and *teachers* of the rest. *A man's mind is as fatally narrowed, and his feelings towards the great ends of humanity as miserably stunted, by giving all his thoughts to the classification of a few insects or the resolution of a few equations*, as to sharpening the points or putting on the heads of pins. The "dispersive speciality" of the present race of scientific men, who, unlike their predecessors, have a positive aversion to enlarged views, and seldom either know or care for any of the *interests of mankind* beyond the narrow limits of their pursuit, is dwelt on by M. Comte as one of the great and growing

the great Military Schools of St. Cyr and Metz, which they enter by competition. They are then kept under the closest surveillance, and are forced to acquire in a short time a great amount of knowledge. No responsibility is allowed them, and until they become officers they are treated in a way no English schoolboy would endure. They consequently never attain habits of command; and as the majority do not enter from the higher classes of Society, have never, even as boys, received the rudimentary training which teaches How to Rule and How to Obey. It is owing, I believe, to the better training in habits of command that the Aristocracy of these countries receive, compared with the other classes of Society, that they

lectual regeneration. To contend against it is one of the main purposes towards which he thinks the forces of society should be directed. The *obvious remedy* is a large and liberal general education preparatory to all special pursuits. And this is M. Comte's opinion; but the education of youth is not in his estimation enough; he requires an agency set apart for obtruding upon all classes of persons through the whole life, *the paramount claims of the general interest, and the comprehensive ideas that demonstrate the mode in which human actions promote or impair it.* In other words, he demands a moral and intellectual authority, charged with the duty of guiding men's opinions and enlightening and warning their consciences; a Spiritual Power, whose judgments on all matters of high moment should deserve, and receive, the same universal respect and deference which is paid to the united judgment of astronomers in matters astronomical. The very idea of such an authority implies that an unanimity has been attained, at least in essentials, among moral and political thinkers, corresponding or approaching to that which already exists in the sciences

are able to take a prominent position in the government of the country more than to their wealth or intellectual attainments.*

* Mr. Matthew Arnold, in his work, "A French Eton," observes in connection with the Royal Commission which was appointed some years ago to report upon the endowments, studies, and management of Eton and the eight other principal English Public Schools, "the reform of an institution (Eton) which trains so many of the rulers of this country, is, no doubt, a matter of considerable importance. . . . . If Eton does not teach her pupils profound wisdom, we have Oxenstiern's word for it that the world is governed by very little wisdom. Eton, at any rate, teaches her aristocratic pupils virtues which are among the best virtues of an aristocracy—freedom from affectation, manliness, a high spirit, simplicity."

LECTURE III.

Introduction—The view different races have had of the Aim of Education—What is our Aim as a Nation?—Definition of Education—The Object according to this Definition—Laws of Nature learned from Observation and Experiment—Illustrations; the Discoveries of Newton and Kepler—Numerous Gradations of Mental Capabilities and Power exist; although the same faculties are common to all—The Reason—Succeeding generations mentally in advance of preceding ones illustrated—People in the same country will ever vary in Intellectual Power and Attainments—One Reason stated—But *all* capable of Intellectual Advancement—The Advancement would be more rapid and perfect were Rational Methods of Instruction followed—Meaning of the terms A Good Education, A Liberal Education, &c.—Value of the Classics and Mathematics as Educational Instruments in training the Mind—The Mind exercised by these Studies only in Deductive Reasoning—One at least of the Inductive Sciences ought therefore to be taught in Secondary Schools—For Educational purposes, the Experimental superior to the Observational Sciences—Chemistry superior to Physics—Educational Reforms—Teaching the Teachers.

This lecture, and some of the following ones, will be devoted in part or entirely to the consideration of the methods for teaching Chemistry, and its value as an instrument of general education when taught in accordance with the laws of Mental Action. I am bound to tell, as the late Miss Harriet Martineau expresses it in her work on

Household Education, the best I know on the subject. I shall have, therefore, to draw to a great extent upon my own experience as a student and teacher of the Science, which, after all, is the best source for what one has to say on this as on most other subjects.

Mr. Herbert Spencer in one of his admirable essays on Education, that on "What Knowledge is most Worth," states "that, in order of time, decoration precedes dress. Humboldt," he says, "tells us that an Orinoco Indian, though quite regardless of bodily comfort, will yet labour for a fortnight to purchase pigment wherewith to make himself admired; and that the same woman who would not hesitate to leave her hut without a fragment of clothing on, would not dare to commit such a breach of decorum as to go out unpainted. It is curious, observes Mr. Spencer, that the like relations hold with the mind. Among mental as among bodily acquisitions, the ornamental comes before the useful. Men dress their children's minds as they do their bodies—in the prevailing fashion. As the Orinoco Indian puts on paint before leaving his hut, not with a view to any direct benefit, but because he would be ashamed to be seen without it; so, a boy's drilling in Latin and Greek is insisted on, not because of their intrinsic value, but that he might not be disgraced by being found ignorant of them—that he may

have the education of a gentleman—the badge marking a certain social position and bringing a consequent respect."*

* The distribution of prizes competed for by the students of the metropolitan and provincial Lyceums took place to-day, Aug. 4, 1880, at the Sorbonne. The Minister of Public Instruction, M. Jules Ferry, presided. All the Professors of the various Lyceums and Colleges, and those of the different Faculties in Paris, were present. M. Jules Ferry, whose speech, contrary to custom, was not printed, began by saying that they were bidding a last farewell to Latin as a language for use. The study of it, as well as of the Greek, had in the past been an invaluable means for the culture of the human mind; but the study of antiquity had degenerated into superstition, into grammatical idolatry. Common sense and truth must be returned to. Henceforth Latin and Greek were to be studied, not for the sake of writing in those tongues, but merely to read the great classic productions, and glean from them all the wisdom which they contained. The University of 1880, then, not less grateful to the past but more enlightened than its predecessors, had resolved to repudiate the teaching of the dead languages. No one would lose anything by the new régime, unless it were the purveyors of degrees at fixed prices, or the rejected of the Universities; and no pity need be felt for either of those classes. M. Ferry then proceeded to discuss the new programme for the elementary classes, which had been elaborated by the Council of Public Instruction. This, he said, would quite sweep away the old system, which had converted school into a prison. What they aimed at was to make it into a garden. A child's mind could not assimilate knowledge except when presented in a concrete form. By the new method, the great object of which was to bring the minds of teacher and pupil into closer contact, that the acquisition of knowledge might become a natural development, school would become a pleasure instead of a punishment. A just and beneficent law had put an end to the pernicious system by which education had suffered for thirty years. Tolerated, harassed, humiliated, supervised by its rivals, governed sometimes by its slanderers, suffering alternately from the hostile forces bent upon its ruin and the feeble friends incapable of defending it, the University only yesterday was reduced to a bureaucracy;

Miss Harriet Martineau, in the chapter on "What Schooling is for," in the work I have already alluded to, notices the different accounts different people have given, and now give, of the aim of education. The Patriarchs some thousand years ago had their ideas, so had the Spartan, and so had the Jew in his own Palestine. Miss Martineau when she visited America came in contact with three different races of people who had their notions on the subject, and they were as wide of each other as those of the Patriarch, the Spartan, and the Jew. The White people (Americans) had their notions, and they were pretty much the same as our own; there was the Red Indian, his idea of the training of boys resembled the Spartan's idea in this—they, the Indian and the Spartan, both trained their boys as warriors, but they differed in the object; the Spartan looked upon every boy as born to help to preserve the State from enemies without, and from their slave enemies within; therefore the State looked after the Spartan boy from his earliest years, and at the age of seven he was put under public training entirely;

but, thanks to the reconstruction of the Upper Education Council, it had now attained the dignity of a living, organized, and free institution, which would have been permitted by none other than a Republican Government; and this fact was one of which that Government might be proud, and which the University would assuredly not forget. M. Ferry was frequently interrupted by

but the Indian boy is trained to war, not as a Servant of the State, but as an Individual. The third race Miss Martineau came in contact with were the half-breeds, the inhabitants of the island of Macinaw: they were the offspring of the Red Race and the French colonists who first settled on the island; their object seemed to be to train their children to become amphibious.

What is our aim? I think it will be admitted, speaking generally, that as individuals we are pretty much like the Red Indian in this—we think only about the individual boy, not about the community at large, and still less about posterity. But the State through its governing body ought to take a higher and more extended view of Education; it should so direct it, that all the faculties of the mind would be exercised and strengthened; this would confer the highest benefit to be attained by intellectual education on the individual, and likewise on the State and on posterity.*

* The late Bishop Copleston, in replying to the Edinburgh Reviewers and others who, after the manner of Locke, protested that no system of education was of benefit that was not based upon the principle of utility, remarks:—"Two things ought to be kept perfectly distinct—viz., that mode of education which would be most beneficial, as a system, to society at large, with that which would contribute most to the advantage and prosperity of an individual. Now, the peculiar interest of the individual is not always the same, is seldom precisely the same, is even frequently at variance with the interest of the public; and he who serves the one most faithfully, always forgets, and often injures, the other. The

Professor Bain, in his work "Education as a Science," has given definitions of Education by various authorities. I will give the late Dr. Donaldson's definitions of EDUCATION, INFORMATION, KNOWLEDGE, and SCIENCE, as they accord very much with my own views:—"If we confine ourselves to the province of the intellect, EDUCATION is properly a cultivation and development of those faculties which all men have in common, though not all in the same degree of activity. INFORMATION, when it is nothing more, merely denotes an accumulation of stray particulars by means of the memory. On the other hand, KNOWLEDGE is information appropriated and thoroughly matured. We speak of knowledge of the world, knowledge of our duties—all of which imply a completeness and maturity of habit and experience. And when knowledge extends to a methodical comprehension of general laws and principles, it is called SCIENCE. It is the natural and proper tendency of information to ripen into knowledge, just as knowledge itself is

the former—individual interest—is narrow, selfish, and mercenary. It is the mode of education which would fit for a specific employment, or contribute most to individual advantage and prosperity, on which the world are most eager to inform themselves; but the persons who instruct them, however they may deserve the thanks and esteem of those whom they benefit, do no service to mankind. There are but so many good places in the theatre of life, and he who puts us in the way of procuring one of them does to us indeed

not complete until it is systematized into science. And as intellectual education necessarily presumes a certain increase in the information of acquired knowledge of the person under training, it is clear that while the main object of education—namely, the gradual development of the faculties—should never be neglected, the *information* conveyed, and *the method of imparting it*, should be such as to lay the foundation and pave the way for the superstructure of knowledge and science."

If the definition of Education given be correct, the aim of it is to train and cultivate the powers of the mind, that it will be capable of those higher modes of thinking which are included under the term REASON: the matter, therefore, to be taught ought always to be viewed as of much less importance for itself, than as a means of developing and exercising the reasoning powers; but if the *latter* is attained, the *former* will also be attained, and in the highest and most perfect manner. Every human being, the uneducated as well as the educated, reasons; but the former reasons only about particulars, from like to like—he cannot, like the latter, discover that what is true of one thing is equally true of many other things; he is not, in fact, able, except in very simple cases, to generalize—that is, draw a general law from particular cases; and it is by generalization that the

laws of Nature are learned from observation and experiment.*

Every human being before the time of Newton had observed that heavy bodies fall to the earth; but that great Philosopher reasoned on the facts, and the result of his reasoning led him to discover the Law of Gravity, and that this law governed not alone mundane matter, but that of other worlds. "If it were true," as the late Dr. *Whewell observes in his work on the Inductive* Sciences, "that the fall of an apple was the occasion of Newton's pursuing the train of thought which led to the doctrine of universal gravitation, the habits and constitution of Newton's intellect, and not the apple, were the real source of this great event in the progress of knowledge."

Kepler, who has been termed, from his wonderful discoveries, the Legislator of the Heavens, and whose grand discoveries of the elliptical motion of the planets prepared the way for the still greater

* "General reasonings seem intricate, merely because they are general; nor is it easy for the bulk of mankind to distinguish, in a great number of particulars, that common circumstance in which they all agree, or to extract it pure and unmixed from the other superfluous circumstances. Every judgment or conclusion with them is particular. They cannot enlarge their view to those universal propositions which comprehend under them an infinite number of individuals, and include a whole science in a single theorem. Their eye is confounded with such an extensive prospect; and the conclusions derived from it, even though clearly expressed, seem

discoveries of Newton, as Kepler's *laws* became the *facts* upon which Newton founded his; when he found that the hypotheses he had conceived with regard to the planetary orbits were correct, could not help exclaiming, "O God! I think thy thoughts after Thee." And when, after he had discovered the curve described by planets, and traced the law of the planets' motion, he sought and found what may be termed "a brotherhood of worlds," a mighty and magnificent scheme of vast revolving orbs. When success crowned his efforts, he could scarcely believe his own senses. He feared some demon mocked him. He therefore went over his work again and found it correct: "Full conviction then burst upon his mind, he had won the goal; the struggle of seventeen long years was ended; God was vindicated; and the philosopher, in the wild excitement of his glorious triumph, exclaimed—'Nothing holds me. I will indulge my sacred fury! If you forgive me, I rejoice; if you are angry, I can bear it. The die is cast. The book is written, to be read either now or by posterity, I care not which. It may well wait a century for a reader, since God has waited six thousand years for an observer!'"*

The late Lord Lytton, in the beautiful dedication of "Zanoni" to Gibson, the Great Sculptor, at Rome,

* "The Orbs of Heaven." By O. M. Mitchell, A.M.

states, in words not less cogent than those of Kepler, that he can wait for his well-beloved work to be appreciated. He says—"I, Artist in words, dedicate then, to you, Artist whose ideas speak in marble, this well-beloved work of my matured manhood. I love it not the less because it has been little understood and superficially judged by the common herd; it was not meant for them. I love it not the more because it has found enthusiastic favourers among the Few. My affection for my work is rooted in the solemn and pure delight which it gave me to conceive and to perform. If I had graven it on the rocks of a desert, this apparition of my own innermost mind, in its least clouded moments, would have been to me as dear; and this ought, I believe, to be the sentiment with which he whose Art is born of faith in the truth and beauty of the principle he seeks to illustrate, should regard his work. Your serener existence, uniform and holy, my lot denies if my heart covets. But our true nature is in our thoughts, not our deeds: and therefore, in Books —which *are* his Thoughts—the Author's character lies bare to the discerning eye."

One of the objects I have had in view (others will appear as we proceed) in introducing the opinions of these distinguished men, is to show the Young Student that Great and Noble Minds do not mentally toil for the sake of so-called Fame or

Renown; they consecrate their talents to the discovery of TRUTH, the enlargement of KNOWLEDGE, and for the *happiness and benefit* of MANKIND.*

From the God-like intellects of a Newton and a Kepler down to the lowest in the scale of human intelligence, numerous gradations of mental capabilities and power exist, although the same mental faculties are common to all; the differences in degree arising, as we have seen (page 53), from the difference in growth of the intellect; the mental powers, like the bodily organs, requiring appropriate exercise for their proper and most perfect development—and that development is transmissible hereditarily; hence the difference in mental aptitude between individuals of the same race and between different races is owing to the less cultivation of the mind by the individual and in most cases by his progenitors; and the like applies to different races. The late Baron Liebig and others have given striking illustrations of this progressive development of the mind.

Liebig observes—"In our schools mere children

* The most incessant occupation of the human intellect throughout life is the ascertainment of *truth*. We are always needing to know what is actually true about something or other. It is not given to us all to discover great general truths, that are a light to all men and to future generations; though *with a better general education*, the number who could do so would be far greater than it is."

are now taught truths, the attainment of which has cost immense labour and indescribable efforts. They smile when we tell them that an Italian philosopher wrote an elaborate treatise to prove that the snow found upon Mount Etna consists of the same substance as the snow upon the Alps at Switzerland, and that he heaped proof upon proof that both these snows, when melted, yielded water possessed of the same properties. And yet this conclusion was really not so very palpable, since the temperature of the two climates so widely differ, and no one in those days had any notion of the diffusion of heat over the surface of the earth. When a schoolboy takes a glassful of liquid, and, placing a loose piece of paper over it, inverts the glass without spilling a drop of its contents, he only astonishes another child by his performance; and yet this is the identical experiment which renders the name of Torricelli immortal. It is a variation of that experiment with which the burgomaster of Magdeburgh (Otto von Guericke) threw the Emperor and the princes of the empire at Ratisbon into speechless astonishment. Our children have more correct notions of Nature and natural phenomena than had Plato! They may treat with ridicule the errors which Pliny has committed in his 'Natural History'!"*

* "Almost within historical periods we can trace the rise of Mathematical Science from its simplest germs. We can prove our

I cannot omit what the late Dr. Whewell states on the same subject—"Indeed, so familiar and evident are the elementary truths of Mechanics when expressed in this simple form, that they are received as truisms; and men are disposed to look back with surprise and scorn at the speculations which were carried on in neglect of them. The most superficial reasoner of modern times thinks himself entitled to speak with contempt and ridicule of Kepler's hypothesis concerning the physical causes of the celestial motions; and gives himself credit for intellectual superiority, because he sees, as self-evident, what such a man could not discover at all. It is well for such a person to recollect, that the real cause of his superior insight is not the pre-eminence of his faculties, but the successful labours of those who preceded him. The language which he has learned to use unconsciously, has been adapted to, and moulded on, ascertained truths. When he talks familiarly of 'accelerating forces' and 'deflections from the tangent,' he is assuming that

descent from ancestors who counted only on their fingers; but how almost *infinitely* is a Newton or a Laplace above those simple savages. Pythagoras is said to have sacrificed a hecatomb when he discovered the Forty-seventh Proposition of Euclid, and the occasion was worthy of the sacrifice. Archimedes was beside himself when he first perceived his beautiful mode of determining specific gravities. Yet these great discoveries are the simplest elements of our schoolboy knowledge. Step by step we can trace upwards the acquirement of new mental powers."—JEVONS.

which Kepler did not know, and which it cost Galileo and his disciples so much labour and thought to establish. Language is often called an instrument of thought; but it is also the nutriment of thought; or rather, it is the atmosphere in which thought lives: a medium essential to the activity of our speculative power, although invisible and imperceptible in its operation; and an element modifying, by its qualities and changes, the growth and complexion of the faculties which it feeds.* In this way the influence of preceding discoveries upon subsequent ones, of the past upon the present, is most penetrating and universal, though most subtle and difficult to trace. The most familiar

* "Is the whole of Mythology an invention, the fanciful poetry of a Homer or Hesiod, or is it a growth? Or, to speak more definitely, was Mythology a mere accident, or was it inevitable? Was it only a false step, or was it a step that could not have been left out in the historical progress of the human mind?

"*The study of the history of language, which is only a part of the study of the history of thought*, has enabled us to give a decisive answer to this question. Mythology is inevitable, it is natural, it is an inherent necessity of language, if we recognize in language the outward form and manifestation of thought; it is in fact the dark shadow which language throws on thought, and which can never disappear *till language becomes altogether commensurate with thought, which it never will.* Mythology, no doubt, breaks out more fiercely during the early periods of the history of human thought, but it never disappears altogether. Depend upon it, there is Mythology now as there was in the time of Homer, only we do not perceive it, because we ourselves live in the very shadow of it, and because we all shrink from the full meridian light and truth."—Professor MAX MÜLLER *On the Philosophy of Mythology.*

words and phrases are connected by imperceptible ties with the reasonings and discoveries of former men and distant times. Their knowledge is an inseparable part of ours; the present generation inherits and uses the scientific wealth of all the past. And this is the fortune, not only of the great and rich in the intellectual world; of those who have the key to the ancient storehouses, and who have accumulated treasures of their own;—but the humblest inquirer, while he puts his reasonings into words, benefits by the labours of the greatest discoverers. When he counts his little wealth, he finds he has in his hands coins which bear the image and superscription of ancient and modern intellectual dynasties; and that in virtue of this possession, acquisitions are in his power, solid knowledge within his reach, which none could ever have attained to, if it were not that the gold of truth, once dug out of the mine, circulates more and more widely among mankind."

As poverty will never cease out of the land, the people in each civilized country will, if there were no other reasons, ever vary in intellectual power and attainments; but all, even the very loftiest, as men who, like Newton, when compared with their fellow men, appear INSPIRED,* as well

* When Newton conceived and established the law of Gravitation, he added to our knowledge something which was not entertained in any truth previously known, nor deducible from it by any course

as the most uncultivated—are all capable of an intellectual advancement of which none can foresee the limit; for, as regards knowledge, a few pebbles only have as yet been gathered on its shore, compared with the countless number that still remain to be collected; but though boundless as it may appear, there must be a limit to the human understanding, as the finite will never ascend to or reach the Infinite, for that would imply, as Professor Jevons states in his work on the Principles of Science, that "the Creator cannot outstrip the intelligence of His creatures, and that the existing Universe is not infinite in extent and complexity; an assumption for which," he says, "he can see no logical basis whatever."*

As successive generations are in advance, as regards knowledge, of the preceding ones, however defective the system of education adopted of mere reasoning. . . . . However rare the Mathematical talent in its highest excellence may be, it is far more common, if we are to judge from the history of Science, than the genius which divines the general laws of Nature. We have several good mathematicians in every age; we have few great discoverers in the whole history of our species."—WHEWELL.

* "The astronomer can calculate the positions of the heavenly bodies when thousands of generations of men shall have passed away, and in this fact we have some illustration, as Laplace remarks, of the power which scientific prescience may attain. Doubtless, too, all efforts in the investigation of Nature tend to bring us nearer to the possession of that ideally perfect power of intelligence. Nevertheless, as Laplace, with profound wisdom adds, we must ever remain at an infinite distance from the goal of our aspirations."—JEVONS.

has been, it is impossible to realize what could have been and might be accomplished if rational methods of instruction had been and were followed, and instead of teaching only *deductive* Sciences, one at least of the *inductive* ones had been made part of a schoolboy's education. To illustrate this it will be necessary to enter somewhat more fully into the past and present opinions held as regards the subjects that ought to be taught in a good general system of education suitable for secondary schools.

It has been stated in the First Lecture that a scientific education ought to precede a technical one, and the former ought to be preceded by a sound and complete general education, which every one should have the opportunity of obtaining. It will be desirable to introduce this most important branch of the subject by some observations on education generally.

Education is one of the great questions of the day, and the terms "a good education," "a liberal education," "a general education," "a technical education," are constantly being used; but they are used by many with very little meaning or precision. In the time of Plato and Socrates the Athenian higher class had, as teachers for the higher departments of education, men who have been habitually called *Sophists*.* The education

* "Their character (the Athenians) had been greatly injured by

they gave enabled "a young man to write well, speak well, and act efficiently, on all ordinary occasions, public and private, which is what we commonly mean by a *a good education.*" Plato and Socrates could find no solid principles in this teaching, and when they put the questions, what it was "to speak well" and "to act well," the Sophists were unable to answer. If the greater number who employ the terms given above were asked what they meant, it would be found, I think, that they, like the Athenian teachers, would be unable to answer.

A good education signifies to many the education the youths of the higher classes receive; it signifies to others the kind of subjects taught; but it signifies only to the few the complete cultivation of the human mind, and for the attainment of this grand and noble object two essentials are requisite: the employment of the right subjects, as the instruments, in the teaching; and the most perfect and philosophical methods of teaching them, so that all the faculties of the mind are trained and developed harmoniously.

argument with a perfect indifference whether they were used for the furtherance of truth or the propagation of falsehood. These men had managed to be received as the proper instructors of youth; and the rising generation at Athens, instead of being trained in the simple rural habits of a former age, had in consequence become arrogant, without possessing more real knowledge; and were better talkers than their parents, with less of purity, affection, and truth. —*The Five Empires*, by Rev. R. J. WILBERFORCE."

A Liberal education is the opposite of a Professional or Technical education; the general discipline of the mind is the object, or ought to be, of the first, while the cultivation of certain branches of study for ulterior use or application is the object of the latter. With many the term "liberal education" is synonymous with "University education," the Universities being looked upon as especially the seats of that kind of education. But the mere attending the courses of instruction given at a University does not of itself constitute a liberal education, however excellent the educational curriculum may be for the culture of the mind; for if the student only passively receives and does not assimilate the knowledge he is given, he certainly does not obtain a liberal education. But a liberal education is viewed by one who is no mean authority on University teaching as comprehending much more than the mere acquirement of knowledge. He (Cardinal Newman) states: "When this analytical, distributive, harmonizing process is away, the mind experiences no enlargement, and is not reckoned as enlightened or comprehensive, whatever it may add to its knowledge.* For instance, a great memory does

* "The enlargement consists not merely in the passive reception into the mind of a number of ideas hitherto unknown to it, but in the mind's energetic and simultaneous action upon and towards and among these new ideas which are rushing in upon it. It is the

not make a philosopher, any more than a dictionary can be called a grammar. There are men who embrace in their minds a vast multitude of ideas, but with little sensibility about their real relations towards each other. These may be antiquarians, annalists, naturalists; they may be learned in the law; they may be versed in statistics: they are most useful in their own place; I should shrink from speaking disrespectfully of them: still, there is nothing in such attainments to guarantee the absence of narrowness of mind. If they are nothing more than well-read men, or men of information, they have not what specially deserves the name of culture of mind, or fulfils the type of LIBERAL EDUCATION.*

The same high authority states:—"If I had

action of a formative power, reducing to order and meaning the matter of our acquirements; it is a making the objects of our knowledge subjectively our own; or, to use a familiar word, it is a digestion of what we receive, into the substance of our previous state of thought; and without this no enlargement is said to follow. There is no enlargement, unless there be a comparison of ideas one with another, as they come before the mind, and a systematizing of them. We feel our minds to be growing and expanding *then*, when we not only learn, but refer what we learn to what we already know. It is not the mere addition to our knowledge that is the illumination; but the locomotion, the movement onwards, of that mental centre, to which both what we know, and what we are learning, the accumulating mass of our acquirements, gravitates." —CARDINAL NEWMAN'S *Idea of a University*.

* "A liberal education" is thus defined in the *Edinburgh Review*, 1836:—"An education in which the individual is cultivated, not as an instrument towards some ulterior end, but as an

to choose between a so-called University which dispensed with residence and tutorial superintendence, and gave its degrees to any person who passed an examination in a wide range of subjects, and a University which had no professors or examinations at all, but merely brought a number of young men together for three or four years, and then sent them away as the University of Oxford is said to have done some sixty years since, if I were asked which of these two methods was the better discipline of the intellect—mind, I do not say which is *morally* the better, for it is plain that compulsory study must be a good, and idleness an intolerable mischief,—but if I must determine which of the two courses was the more successful

perfection as a man, not his relative dexterity as a professional man, is the scope immediately in view."

The late Mr. Stuart Mill thus defines it—"This last stage of general education, destined to give the pupil a comprehensive and connected view of the things which he has already learnt separately, includes a philosophic study of the METHODS of the Sciences; the modes in which the human intellect proceeds from the known to the unknown. We must be taught to generalize our conception of the resources which the human mind possesses for the exploration of Nature; to understand how man discovers the real facts of the world, and by what tests he can judge whether he has really found them. And doubtless this is the *crown* and *consummation* of LIBERAL EDUCATION: but before we restrict a University to this highest department of instruction—before we confine it to teaching, not knowledge, but the philosophy of knowledge—we must be assured that the knowledge itself has been acquired elsewhere" (in schools). "But where are such schools to be found? Since Science assumed its modern character, nowhere: *and in these islands less than elsewhere.*"

in training, moulding, enlarging the mind—which sent out men the more fitted for their secular duties, which produced better public men, men of the world, men whose names would descend to posterity, I have no hesitation in giving the preference to that University which did nothing over that which exacted of its members an acquaintance with every science under the sun.

"The true and adequate end of intellectual training and of a University is not LEARNING or ACQUIREMENT, but rather is THOUGHT or REASON exercised upon Knowledge, or what may be called Philosophy."

A general education ought to have for its first and chief object the complete and harmonious development of all the faculties of the mind. The subjects to be taught ought, therefore, to be selected for the purpose of accomplishing this the highest aim of education, and less with regard to the utility of the studies in after-life; but if both objects could be attained by the teaching of certain subjects, that education would be the most perfect in every respect.

Formerly Classics and Mathematics were considered, and even at the present time are considered, by many as the only subjects worthy of being taught. On the other hand, there are many, and an increasing number, who desire to have a multitude of subjects taught in schools; whether

they intend it or not, their object is *quantity*, leaving *quality* to take care of itself; they would force on the yet unformed and undisciplined mind a crowd of disconnected facts, tumbled into the mind in the utmost confusion; this was the way Dr. Blimber and his daughter Cornelia taught little Paul Dombey:—"Our little friend's library," states Dickens in his admirable sketch of this cramming system, "comprised a little English and a deal of Latin; names of things, declensions of articles and substantives, exercises thereon, and preliminary rules; a trifle of orthography, a glance at ancient history, a wink or two at modern ditto, a few tables, two or three weights and measures, and a little general information. When poor Paul had spelt out number two, he found he had no idea of number one; fragments whereof afterwards obtruded themselves into number three, which slided into number four, which grafted itself on to number two. So that whether twenty Romuluses made a Remus, or *hic*, *hæc*, *hoc* was troy weight, or a verb always agreed with an ancient Briton, or three times four was *Taurus*, a bull, were open questions with him."

In an inquiry into this subject the first thing to be ascertained if it can is, What is the independent value of the Classics and Mathematics as educational instruments in training the mind; and

faculties of the mind would be trained and developed harmoniously? If, by the employment of these subjects alone, this could be accomplished, there would be less need to introduce other subjects into the curriculum; but different studies, that act, as it were, alike in exercising the faculties of the mind, nevertheless do not develop them in an equal degree; hence the desirability of employing different studies in the education of youth.

And first, why are the Greek and Latin languages and literature made the chief subjects of school education at the present time? It cannot be for the same reasons Latin was made the groundwork of education in the Middle Ages. "Latin was then taught, not for the beauty of its classical literature, nor because the study of a dead language was the best mental gymnastic, or the only means of acquiring a masterly freedom in the use of living tongues, but because it was the language of educated men throughout Western Europe, employed for public business, literature, philosophy, and science, above all, in God's providence, essential to the unity, and therefore enforced by the authority, of the Western Church."*

* "Ecclesiastics at that time transacted the business of civil departments requiring education. Libraries were armouries of the Church: grammar was part of her drill. The humblest scholar was enlisted in her service: she recruited her ranks by founding Latin schools. If a boy of humble birth had a taste for letters, or if a boy of high birth had a distaste for arms, the first step was

In considering the aim and object of teaching Latin and Greek to boys at the present day, we will, as in the previous Lecture, summon into court, as it were, a few eminent men, and hear what they have got to say on the subject.

De Quincey, in his "Letters to a YoungMan whose Education had been Neglected," thus advises him with regard to the learning of languages :—"But to you who have no such purposes as professed philologists have, and whom I suppose to wish for languages simply as avenues to literature not otherwise accessible, I will frankly say, start from this principle—that the act of learning a language is in itself an evil ; and so frame your selection of languages, that the largest possible body of literature, *available for your purposes* shall be laid open to you at the least possible price of time and mental energy squandered in this direction. I say this with some earnestness. For I will not

to learn Latin. His foot was then on the ladder. He might rise by the good offices of his family to a bishopric, or to the Papacy itself by merit and the grace of God. Latin enabled a Greek from Tarsus (Theodore) to become the founder of learning in the English Church; and a Yorkshireman (Alcuin) to organize the schools of Charlemagne. Without Latin, our English Winfrid (St. Boniface) could not have been the apostle of Germany and reformer of the Frankish Church; or the German Albert master at Paris of Thomas Aquinas; or Nicholas Breakspeare Pope of Rome. With it, Western Christendom was one vast field of labour: calls for self-sacrifice, or offers of promotion, might come from north or south, from east or west."—Mr. CHARLES STUART PARKER, M.A., *On the History of Classical Education.*

conceal from you, that one of the habits most unfavourable to the growth and sincere culture of the intellect in our day, is the facility with which men surrender themslves to the barren and ungenial labour of language-learning. Unless balanced by studies that give more exercise, more excitement, and more aliment to the faculties, I am convinced, by all I have observed, that this practice is the dry-rot of the human mind. How should it be otherwise? The act of learning a science is good, not only for the knowledge which results, but for the exercise which attends it; the energies which the learner is obliged to put forth are true intellectual energies, and his very errors are full of instruction. He fails to construct some leading idea, or he even misconstructs it; he places himself in a false position with respect to certain propositions; views them from a false centre; makes a false or an imperfect antithesis; apprehends a definition with insufficient rigour; or fails in his use of it to keep it self-consistent. These and a thousand other errors are met by a thousand appropriate resources—all of a true intellectual character; comparing, combining, distinguishing, generalizing, subdividing, acts of abstraction and evolution, of synthesis and analysis, until the most torpid minds are ventilated and healthily excited by this introversion of the faculties upon themselves.

"But in the study of language (with an exception, however, to a certain extent, in favour of Greek and Latin), nothing of all this can take place, and for one simple reason—that all is arbitrary. Wherever there is a law and system, wherever there is relation and correspondence of parts, the intellect will make its way—will interfuse amongst the dry bones the blood and pulses of life, and 'create a soul under the ribs of death.' But whatsoever is arbitrary and conventional—which yields no reason why it should be this way rather than that, obeying no theory or law—must, by its lifeless forms, kill and mortify the action of the intellect. If this be true, it becomes every student to keep watch upon himself, that he does not, upon any light temptation, allow himself an overbalance of study in this direction; for the temptations to such an excess, which in our days are more powerful than formerly, are at all times too powerful. Of all the weapons in the armoury of the scholar, none is so strong or so captivating to commonplace minds as skill in languages. *Vanity* is, therefore, one cause of the undue application to languages. A second is the national *fashion.*"

Mr. John Stuart Mill observed, in addressing the students at St. Andrews: "If there were no more to be said than that scientific education teaches us to think, and literary education to

express our thoughts, do we not require both? and is not any one a poor maimed, lopsided fragment of humanity who is deficient in either? . . . . The only languages, then, and the only literature, to which I would allow a place in the ordinary curriculum, are those of the Greeks and Romans; and to these I would preserve the position in it which they at present occupy. That position is justified by the great value, in education, of knowing well some other cultivated language and literature than one's own, and by the peculiar value of those particular languages and literatures. . . . . But if it is so useful, on this account, to know the language and literature of any other cultivated and civilized people, the most valuable of all to us in this respect are the languages and literature of the ancients. No nations of modern and civilized Europe are so unlike one another, as the Greeks and Romans are unlike all of us; yet without being, as some remote Orientals are, so totally dissimilar, that the labour of a life is required to enable us to understand them. . . . . Even as mere languages, no modern European language is so valuable a discipline to the intellect as those of Greece and Rome, on account of their regular and complicated structure. Consider for a moment what grammar is. It is the most elementary part of logic. It is the beginning of the analysis of the thinking process. The principles and rules of

grammar are the means by which the forms of language are made to correspond with the universal forms of thought. The distinctions between the various parts of speech, between the cases of nouns, the moods and tenses of verbs, the functions of particles, are distinctions in thought, not merely in words. Single nouns and verbs express objects and events, many of which can be cognized by the senses; but the modes of putting nouns and verbs together, express the relations of objects and events, which can be cognized only by the intellect; and each different mode corresponds to a different relation. The structure of every sentence is a lesson in logic. The various rules of syntax oblige us to distinguish between the subject and predicate of a proposition, between the agent, the action, and the thing acted upon; to mark when an idea is intended to modify or qualify, or merely to unite with, some other idea; what assertions are categorical, what only conditional; whether the intention is to express similarity or contrast, to make a plurality of assertions conjunctively or disjunctively; what portions of a sentence, though grammatically complete within themselves, are mere members or subordinate parts of the assertions made by the entire sentence. Such things form the subject-matter of universal grammar; and the languages which teach it best are those which have the most definite

rules, and which provide distinct forms for the greatest number of distinctions in thought; so that if we fail to attend precisely and accurately to any of these, we cannot avoid committing a solecism in language. In these qualities the classical languages have an incomparable superiority over every modern language, and over all languages, dead or living, which have a literature worth being generally studied. But the superiority of the literature itself, for purposes of education, is still more marked and decisive."

"Nothing has more contributed in this country to disparage the cause of classical education than the rendering it the education of all. That to many this education can be of little or no advantage is a truth too manifest to be denied; and on this admission the sophism is natural, to convert 'useless to many' into 'useful to none.' With us, the learned languages are at once taught too extensively, and not intensively enough; an absurdity in which we are now left almost alone in Europe."*

Professor Pillans, in his Lectures on the relative Utility of Classical Instruction, remarks: "The strongest case against the advocates for classical education is, the practice that has hitherto prevailed of making it so general as to include boys

of whom it is known beforehand that they are to engage in the ordinary pursuits of trade and commerce, who are not intended to prosecute their education further than school, and are not therefore likely to follow out the subject of their previous studies much, or at all, beyond the period of their attendance there. I willingly allow, and have already admitted, that a youth who looks forward from the very outset to the practice of some mechanical or even purely scientific art, may employ his time better, in acquiring manual dexterity and mathematical knowledge, than in making himself imperfectly acquainted with a dead language."

"It will not be denied that in the English, French, and German languages, there is a sufficiency of good literature to fill the leisure of a person engaged in any active calling, a sufficiency of works calculated to give a high kind of enjoyment, and to cultivate, very adequately, the literary taste. And if such a person was ever visited by a painful hankering after the time-honoured volumes that were sealed to him, he might console himself by taking note how often his contemporaries, who had enjoyed a complete classical education, were in the habit of taking down these master-pieces from their shelves. For I cannot help thinking that classical literature, in spite of its

the mass even of cultivated persons at the present day. I wish statistics could be obtained of the amount of Latin and Greek read in any year (except for professional purposes), even by those who have gone through a complete classical curriculum. From the information that I have been able privately to obtain, I incline to think that such statistics, when compared with the fervent admiration with which we all still speak of the classics, upon every opportunity, would be found very startling. I am willing to admit that those who have a genuine preference for the classics are persons of the purest, severest, and most elevated literary taste; and I cannot conceive that these relics will ever cease to be reverently studied by those who aspire to be artists in language. But this by no means proves that they ought to occupy the place they do in the training of our youth."*

We have now to consider whether instruction, linguistic and literary, in these two languages, is the best educational instrument that can be employed for developing most perfectly and harmoniously the mental faculties. That memory is largely exercised in the acquirement of any language is known to all; and that habits of accuracy and quickness are acquired in the application of rules to the particular cases, and in the

* "The Theory of Classical Education." By Henry Sidg-

application of the rules the reasoning faculties in practical processes of deduction are exercised and strengthened, is also obvious. But it can scarcely be said that in the *learning* of a language the mind is exercised in inductive reasoning; Dr. Donaldson—no mean authority—states that deductive habits only are developed; and Mr. Sidgwick thinks that induction only comes into play when the student is so far advanced that he stands on a level with the authors of his grammars and dictionaries, and from time to time observes new rules of usage which they have not noted.

"As mere languages, no modern European language is so valuable a discipline to the intellect," Mr. J. S. Mill states, "as those of Greece and Rome, on account of their regular and complicated structure. Classical literature furnishes," states the same authority, "the most *perfect types* of the Art of Expression; and the physical sciences *those* of the Art of Thinking. *Mathematics*, and its application to Astronomy and Natural Philosophy, are the most complete example of the discovery of truths by reasoning; *experimental science*, of their discovery by direct observation."

Whether and to what extent the study of Mathematics conduces to the development of the higher faculties of the mind, was very fully discussed some years ago in a review* attributed to

the late Sir William Hamilton, of a work, "Thoughts on the Study of Mathematics as a part of a Liberal Education," by the late Dr. Whewell. "That language and reason, the conjoined attributes of humanity," Dr. Whewell states in this work, "admit of independent cultivation; and that while classical and grammatical studies furnish us with the means of education in regard to the former faculty, we must go to Mathematics for the best cultivation and development of the reason." In the same work he states, "that, inasmuch as in a good education we must educate the reason as well as the literary taste, we must require of our students a mathematical combined with a classical culture. Owing to the vast preponderance of encouragement to classical reading which the condition of English culture offers," he says, "it will be seen how important it is for those who know that mere classical reading is a narrow and enfeebling education, to resist any attempts to add to this preponderance by diminishing the encouragement which the University gives to studies of a larger or more vigorous kind."

The Reviewer states: "Of all our intellectual pursuits, the study of the mathematical sciences is the one, whose utility as an intellectual exercise, when carried beyond a moderate extent, has been most peremptorily denied by the greatest number of the most competent judges. . . . . If we consult

reason, experience, and the common testimony of ancient and modern times, none of our intellectual studies tend to cultivate a smaller number of the faculties, in a more partial manner, than mathematics. This is acknowledged by every writer on education of the least pretension to judgment and experience; nor is it denied even by those who are most decidedly opposed to their total banishment from the sphere of a liberal instruction. . . . . How opposite are the habitudes of mind which the study of the mathematical and the study of the philosophical sciences require and cultivate, has attracted the attention of observers from the most ancient times. The principle of this contrast lies in their different *objects*, in their different *ends*, and in the different *modes of considering their objects*; differences in the sciences themselves, which calling forth, in their cultivators, different faculties, or the same faculty in different ways and degrees, determine developments of thought so dissimilar, that in the same individual a capacity for the one class of sciences has, not without reason, been considered as detracting from his qualification for the other. As to their *objects*. In the first place, the mathematical sciences are limited to the relation of quantity alone, or, to speak more correctly, to the one relation of quantities—equality and inequality; the philosophical sciences, on the contrary, are co-extensive with existence and its modes, and circum-

scribed only by the capacity of the human intellect itself. In the second place, mathematics take no account of things, but are conversant solely about notions. Philosophy, on the other hand, is mainly occupied with realities; it is the science of a real existence, not merely of a conceived existence. As to their *ends* and their procedure to these ends. . . . In mathematics, the whole principles are given; in philosophy, the greater number are to be sought out and established. . . . In mathematics the whole science is virtually contained in its *data*; it is only the evolution of a potential knowledge into an actual, and its procedure is thus merely explicative. In philosophy, the science is not contained in *data*; its principles are merely the rules for our conduct in the quest, the proof, and the arrangement of knowledge; it is a transition from absolute ignorance to science, and its procedure is therefore ampliative. In mathematics we always depart from the definition; in philosophy, with the definition we usually end. Mathematics know nothing of causes; the research of causes is philosophy. The truth of mathematics is the harmony of thought and thought; the truth of philosophy is the harmony of thought and existence. The deductions of mathematics being demonstrative, the possibility of the contrary is, at every step, seen to be excluded in the very comprehension of the terms. On the other hand, in philosophy

(with the exception of the science of logic), and in our reasonings in general, such demonstrative certainty is rarely to be attained; probable certainty, that is, when we are never conscious of the impossibility of the contrary, is all that can be compassed. From this general contrast it will easily be seen how an excessive study of the mathematical sciences not only does not prepare, but absolutely incapacitates the mind, for those intellectual energies which philosophy and life require. We are thus disqualified for *observation either internal or external*, for *abstraction and generalization* and for *common* reasoning; and disposed to the alternative of blind *credulity* or irrational *scepticism*. The study of mathematics educates to no sagacity in detecting and avoiding the fallacies which originate in the thought itself of the reasoner. Mathematical reasoning, therefore, as demonstrative, allows no room for any sophistry of thought; the necessity of its matter necessitates the correctness of its form; and, consequently, it cannot forewarn and arm the student against this formidable principle of error. To minds of any talent, mathematics are *only difficult because they are too easy*. It cannot, certainly, be said that the cultivation of mathematics fatigues a single faculty, by urging it to an activity at any moment too intense; in fact, these sciences are felt as irksome, in a great measure, because they do not

allow even the one power they partially occupy its highest healthy exercise. . . . . In mathematics dulness is thus elevated into talent, and talent degraded into incapacity. . . . . We are far from meaning hereby to disparage the mathematical genius which invents new methods and formulæ, or new and felicitous applications of the old; but this we do assert, that the most ordinary intellect may, by means of these methods and formulæ, once invented, reproduce and apply, by an effort nearly mechanical, all that the original genius discovered. The merit of a mathematical invention is, in fact, measured by the amount of thought which it supersedes. Mathematics afford us no assistance either in conquering the *difficulties* or in avoiding the *dangers* we encounter in the great field of probabilities in which we live and move. Of OBSERVATION, EXPERIMENT, INDUCTION, ANALOGY, the mathematician knows nothing. What Dr. Whewell, therefore, alleges in praise of demonstration, 'that the mixture of *various grounds of conviction*, which is so common in other men's minds, is rigorously excluded from the mathematical student's,' is precisely what mainly contributes to render it useless as an exercise of practical reasoning.* In short, the *subtilty of mind*, the

* "In boys, occupied so soon with calculations, the spring of imagination, then so fair and fruitful, is arrested; and they

multiformity of matter, lie far beyond the ken of demonstration; mathematics are not the net by which Psyche shall be caught; nor the chain in which Proteus can be fettered.*

"Are mathematics then of no value as an instrument of mental culture? Nay, do they exercise only to distort the mind? To this we answer, that their study, if pursued in moderation and efficiently counteracted, may be beneficial in the *correction* of a *certain vice*, and in the *formation* of its *corresponding virtue*. The vice is the habit of mental distraction; the virtue the habit of continuous attention. This is the single benefit, to which the study of mathematics can justly pretend,

arithmetic and algebra are limited to the teaching, in a thousand forms, propositions always identical. The problems of life are more complicated; not one is positive, not one is absolute: we must conjecture, we must decide by the aid of indications and assumptions, which bear no analogy with the infallible procedure of the calculus. Demonstrated truths do not conduct to probable truths; which alone, however, serve us for our guide in business, in the arts, and in society."—KIRWAN.

* "It may seem, perhaps, too much a paradox to say, that long habit in this science (mathematics) *incapacitates* the mind for reasoning at large, and especially in the search of moral truth. And yet, I believe, nothing is more certain. The object of geometry is demonstration, and its subject admits of it, and is almost the only one that doth. In this science, whatever is not demonstration is nothing, or, at least, below the sublime inquirer's regard. *Probability*, through its almost infinitive degrees from simple ignorance up to absolute certainty, is the *terra incognita* of the geometrician. And yet here it is, that the great business of the human mind is carried on—the search and discovery of all the important

in the cultivation of the mind; and it is the only one accorded to it by the most intelligent philosophers."*

Classics and mathematics, even if perfect methods were adopted for teaching them, would not exercise fully and completely the reasoning faculties, for in acquiring a knowledge of these subjects the mind is only trained in *deductive reasoning*, which is only one of the two modes of reasoning. In deductive reasoning we reason, as it were, downwards, from the *general* to the *particular*, from causes to effects. By such a procedure no new truth can be generated; general truths can only be pursued into detail; the substance and material of our knowledge cannot therefore be arrived at by that mode of reasoning; they are arrived at by the other and opposite mode—viz., by inductive reasoning. By this latter mode we reason, as it were, upwards—from particular instances, arrived at by observation or experiment, to general conclusions. This mode of reasoning is therefore, if possible, more important than the other, for it is the reasoning we adopt in the affairs of common life. But, irrespective of the collateral advantages either mode of reasoning may have over the other, it is obvious that the

* The reviewer brings forward the opinion of a number of the

mind is *imperfectly trained* when it has been exercised only in one of the two modes, whether it be deductive or inductive.

In a quotation I have given (page 63) from Dr. Whewell, it is stated that the good of education is *twofold ;* it is made up of the value of the acquirement, and of the intellectual benefits obtained in the process of acquiring ; with abler men, it is stated, the first, with inferior ones the second, predominates. If Dr. Whewell meant that able men did not benefit, as well as inferior men, intellectually in the process of acquiring, I think he was in error. The self-taught, however extensive may be their acquirements, rarely overcome the disadvantages from their minds having been imperfectly trained in the acquiring. Let us consider for a moment what training effects in other directions. A well-trained athlete is an example of what good training can accomplish for developing and invigorating the limbs ; the disciplined soldier is an example of the effects of training on physical courage—the undisciplined, although in courage he may be superior naturally to the disciplined one, is no match for him on the field of battle ; those endowed naturally with the most musical of voices resort to a *trainer* of singers, in order that their natural gift may, by proper training, be improved. If training in these and other directions can effect so much, what would

not be effected if the right instruments, and the most perfect employment of them, were employed in exercising, strengthening and enlarging the mind.

As the study of languages and mathematics trains the mind in deductive habits only, it is necessary for the proper and complete cultivation of the mind that one at least of the inductive sciences should be taught in secondary schools as well as in colleges. Whichever of these sciences is taught, should, as far as the student proceeds in the study of it, be taught thoroughly; for he then not only obtains the greatest advantage from it in the training of the mind, but he is also able in after-life to pursue the further study of it, and by the thorough knowledge he has acquired of that science he is able to *teach himself* any other *cognate* one.

It is neither possible in school or college to study efficiently every useful branch of general knowledge; and a smattering of several sciences, for example, and a thorough knowledge of one, are not the same thing It is therefore not desirable, in the interests of efficiency, to include in the curriculum of school studies all or even several of the inductive sciences; a selection has therefore to be made, and the one that exercises the mental powers and habits in a manner the most *diverse* to the exercise induced by the other subjects

taught, must be the most valuable for mental training.

The experimental sciences are much superior to the sciences of observation for educational purposes: Sir John Herschell has called mere observation passive, and experiment active, observation; and Mr. John Stuart Mill says experiment is observation in its most accurate form. Of the two experimental sciences, Chemistry and Physics, or Natural Philosophy, I believe the former science is in almost every respect superior to the latter for training and disciplining the mind, and for reasons which I will briefly state. Physics, viewed purely as an experimental science, may be regarded as simply a branch of Chemistry; in fact, many of the most important of the discoveries in this domain of the science were discovered by chemists—the chemical changes, for instance, which take place in the different forms of the galvanic battery, the electrolytic reduction of metals, &c., cannot be properly understood or explained without a practical acquaintance with Chemistry; hence the experimental part of the science is frequently taught in educational institutions by the chemical teachers. But, unlike experiments purely chemical, which as yet are only qualitative, many of those belonging to the department of Physics have, from the application of Mathematics, been converted into quantitative ones. M. Comte states

in his "Cours de Philosophie Positive"—"Mathematical analysis introduces itself into this science (Physics) only indirectly—that is, after the phenomena have been first brought, by an experimental inquiry, more or less difficult, to some geometrical or mechanical laws, and then it is not properly to Physics that analysis applies itself, but to Geometry or Mechanics. Among other examples, in a geometrical point of view, we may mention," he states, "the theories of reflection and refraction, and, in a mechanical point of view, the study of gravity, &c." The purely experimental portion of the science is therefore comprehended and understood by the chemist, and the mathematical portion by the mathematician. Teachers of this science have sometimes been met with who had neither a knowledge of Chemistry nor Mathematics; the only qualification they had for teaching the subject consisted in being able to put pieces of apparatus together, and performing, of course unintelligently, the experiments. But the proper teaching of the science could no more be attempted by such so-called teachers, than chemical science could be taught by one who had been a porter in a chemical laboratory, and who, without knowing anything of the science, had learned how to make or manufacture chemical preparations by rule of thumb.

Treatises on Physics unavoidably consist more of deductive than of inductive reasoning; Physics

being, therefore, more allied, than Chemistry is, to Mathematics, the study of it does not exercise the faculties of the mind in habits and modes of thought as diverse to those induced by the study of Mathematics as the study of Chemical Science does; further, the reasoning with respect to Physics admits more of demonstrative, and less of probable, certainty, than reasoning on Chemical facts and principles admits of. Some years ago, in a Preface to one of my works,* I thus expressed my views with regard to the advantages to be derived from the study of Chemistry in this respect:—"If it (Chemistry) were taught in harmony with the laws of thought, I believe it would prove as valuable an instrument in perfecting the reason as Mathematics, whilst from its less rigidity, on account of the greater number of conditions and possibilities which have to be taken into consideration in chemical research, it trains the mind on that very account, if I may employ the language of a distinguished statesman in a slightly altered sense, 'to take more sensible and practical views of the probabilities and the possibilities affecting our daily life, upon which far more than upon abstract reasoning the happiness of mankind depends.'† When viewed also in the light of

* "The First Step in Chemistry: a New Method of Teaching the Elements of the Science." Fourth edition.

† "Primary and Classical Education." An Address by the Hon. Robert Lowe (Lord Sh...

useful knowledge, the value of Chemistry can scarcely be over-estimated, especially in the present day; for in addition to its utility to those who have more immediately to conduct and superintend branches of industry which are the result of its applications, it is no less important to those—and the number is constantly increasing on account of the Limited Liability Acts that have become law—who become directors of companies who undertake chemical industries. A *real* knowledge of the science is thus every day becoming more important to the public in general in every civilized country."

But in order to derive these advantages from the study of the science, the mode of teaching it must harmonize as perfectly as possible with the faculties of the mind in their mode and order of unfolding; and this, I am afraid, is a mode of teaching it that is very rarely adopted. But as the teaching of it will be fully discussed in some of the following Lectures, I will not pursue the subject further in the present one.

In concluding this Lecture, I would endeavour again to impress upon those who may read this book, especially upon those interested in Technical Education, the necessity of having, as the foundation, a good General Education. One of the difficulties I have met with in teaching Chemistry to some students arose from their ignorance of some of

the common rules of arithmetic; even some who were at the time studying mathematics were ignorant of the Rule of Three. Little can be done, compared with what might be done, with the *average* student, unless he has received a good general education; and by that I do not mean that he must have studied many subjects, but the subjects he has been taught, and as far as he has been taught them, he must know. We have seen (page 4) that the principals of French industrial establishments complained of the want of primary education in their workmen.

And there must be unity of design, if success is to be attained, in our various educational institutions. The teachers in the primary schools must not be expected to teach more than the rudiments of an ordinary general education; if they were able to teach agriculture, natural science, and all the subjects that some of our Legislators seem to require of them, they would be the superiors in learning to the Master of Trinity College, Cambridge, or the Provost of Trinity College, Dublin.

But if we are to reform our educational system, whether it relates to General education, Scientific education, or Technical education, it can only be effected, in any reasonable time, by the educated public assisting Educational Reformers, by insisting on the reforms required for making our educational institutions *as perfect at least* as the German

ones. Reforms are always slow, but Mr. John Stuart Mill thought they were the slowest in schools. He said: "A few practical reformers of school tuition, of whom Arnold was the most eminent, have made a beginning in many things; but reforms, worthy of the name, are always slow, and reform—even of Governments and Churches—is not so slow as that of schools, *for there is the great preliminary difficulty of fashioning the instruments, of teaching the teachers.*"

LECTURE IV.

The operations of the Mind briefly described—The Primordial Forms of Mental Activity—Nature and Development of Perception—Residua—The Blending of Residua—Nature and Development of Ideas—Association of Ideas—Language the Atmosphere in which Thought lives—Misuse of Language in Teaching the Inductive Sciences—Memory—Its Culture—Constructive Imagination—Creative Imagination—The Logical Processes of the Mind—Necessary and Contingent Truths—Deductive and Inductive Reasoning—Intelligence as Thought.

In order to be able to judge correctly whether a subject—say Chemistry—is taught in accordance with the laws of thought, which is the only true and rational method of teaching any subject, it is necessary to be acquainted with the various ascending stages of the intellectual powers, and the operations of the mind involved in reasoning. This Lecture will therefore be devoted to this important subject; we shall then be prepared to consider the merits and demerits of the different methods which have been proposed or adopted for teaching Chemistry and Chemical Technology.

The entire phenomena of the human mind are, by an almost universal consent, classified under

those of the INTELLECT, the EMOTIONS, and the WILL.* We shall deal only with the INTELLECT,† which requires for its growth, as the body does, nutriment as well as exercise; but whilst the actions constituting the life of the body, as digestion, circulation, respiration, excretion, secretion, &c., are synchronous, the actions constituting thought do not occur together, but one after another.

In passing over the Primordial forms of mental

* "All classifications in modern Psychology come at last to this practical conclusion, *that man is sometimes in a predominant state of intelligence, sometimes in a predominant state of feeling, and sometimes in a predominant state of action and determination.* To call these, however, *separate faculties* is altogether beside the mark. No act of intelligence can be performed without the Will, no act of determination without the Intellect, and no act either of the one or the other without some amount of Feeling being mingled in the process. Thus, whilst they each have their own distinctive characteristics, yet there is a perfect unity at the root. So much indeed is this the case, that the three always answer and correspond to each other. For every stage of *Intellectual* development there is a corresponding stage of Emotion and Will; and the human elements which enter into a given elevation of thought, must enter equally into the same elevation both of our *voluntary* and *emotional* nature."—MORELL.

† "The primary or fundamental attributes of the intellect are, according to Professor Bain—(1) Consciousness of *Difference*, (2) Consciousness of *Agreement* or *Similarity*, and (3) *Retentiveness*. Every properly intellectual function involves one or more of these attributes, and nothing else.

(1) "The fundamental property of Discrimination is also expressed as the Law of Relativity. As we can neither feel nor know without a transition or change of state, every feeling and cognition must be viewed as in relation to some other feeling or cognition. The sensation of heat has no absolute character; there is in it a transition from a previous state of cold, and the sensation

activity, as *vital force, nerve force, mind force,* and *preconscious mental activity,* we may observe that the forces we have named can, like the physical forces, *heat, light, electricity,* &c., be transformed into each other. Force, like matter, is never lost; it is only transmuted from one form of activity into another.

How we come to a consciousness at all of external objects remains still undiscovered, although numerous theories have been constructed to

is wholly relative to that state. It is known, with regard to the feelings generally, that they subsist upon comparison: the pleasure of good health is relative to ill health; wealth supposes comparative indigence. Also as regards knowledge, everything known is known in contrast to something else. There cannot be a single or absolute cognition.

(2) "The conscious state arising from Agreement or Similarity in the midst of Difference, is equally marked and equally fundamental. Supposing one experienced, for the first time, a certain sensation, as redness, and after being engaged with other sensations to encounter redness again, we are struck with the feeling of identity or recognition; the old state is recalled at the instance of the new, by the fact of agreement, and we have the sensation, if not together with a new and peculiar consciousness, the consciousness of agreement in diversity. As the diversity is greater, the shock of agreement is more lively. All knowledge finally resolves itself into Difference and Agreement.

(3) "The attribute of Retentiveness has two aspects or degrees. First, the persistence or continuance of the mental agitation after the agent is withdrawn. When the ear is struck by the sound of a bell, there is a mental awakening, termed the sensation of sound; and the silencing of the bell does not silence the mental excitement—there is a continuing though feeble consciousness, which is the memory or idea of the sound. Secondly, there is a further and higher power—the recovering, under the form of ideas, past and dormant impressions, without the originals, and by mere mental agencies."

bridge over the gulf which lies between matter and mind. Our THOUGHTS belong to, or are part of, ourselves. THINGS are independent of us, and are without; we do not make them, but we make our thoughts by thinking about them. "In all *human knowledge* both THOUGHTS and THINGS are concerned."

PERCEPTION is the operation of the mind which converts sensations into experience, for neither the operations of the Intellectual Powers nor the higher Emotional States are *immediately* called forth by Sensations. By Perception we recognize an object external to us. A subjective sensation is the first act called forth by the presence of that object, whatever it may be. Recognition of the *externality* of the cause of that sensation next follows; and lastly, a *notion* is formed respecting the quality of the object which called it forth. There can, of course, be no perception without attention. The mental act which takes place when we first look upon an object we have not seen before, is one of SEPARATION and COMPARISON; and this act of separation and comparison "forms the first link in the whole vast chain of mental development which ensues. Every succeeding act of our mind's development is only a more progressive act of separation and comparison."*

* Professor Max Müller, when speaking of Comparative Philology, says—"People ask, What is gained by comparison?

In our examination of the systems followed in teaching Chemistry, and the text-books of that science, I shall not unfrequently have to direct attention to this fundamental law of the mind, and how far it is obeyed in those systems and books.

Perceptions pass away from the consciousness—fade, as it may be termed, from the memory; but they can, as all know, be brought again within the sphere of consciousness by the revival in the memory of some association or connecting link. Many interesting illustrations on this point are given in works on Pyschology. Sir W. Hamilton mentions that on one occasion the thought of certain German systems of education followed immediately on the thought of Ben Lomond. Being interested to know how this was, he instituted a psychological search, and found that the last time he was on Ben Lomond he met a German professor there, with whom he conversed on this topic. How impressions, when they pass into the unconscious form, are still so retained in the mind, that if the proper conditions occur, they are again revivified, we know not. Dr. Morrell has em-

Why, all the higher knowledge is acquired by comparison, and rests on comparison. If it is said that the character of scientific research in our age is pre-eminently comparative, this really means that our researches are now based on the widest evidence that can be obtained, on the broadest inductions that can be grasped by the

ployed the term *residua* for these faded impressions: he says, "there must be residua left in the structure of the nerves, or the soul, or both, which ensures the possibility of reminiscence."

In whatever form the impression is left, one thing is certain, that every time a perception recurs, its tendency to recur again has been greatly increased. It is in this way that every one becomes quick in the perception of his own particular business; and of two or more men who are engaged in the same avocation, be it that of law, medicine, &c., the perceptions of the one who has the most practice will—other mental conditions being equal—be the most intense. "The importance," Mr. Morrell states, "of this question, educationally, can hardly be overstated. If we really hold here, in our hand, the *law* by which our primary intellectual tendencies, dispositions, and faculties are created, then the work of the EDUCATOR, so far as the perceptive faculty goes, is obvious. We learn from our perceptions exactly what the mind is trained to learn."

It would seem impossible for a residuum to be retained of each separate thing; at all events, there comes early into play in the life of the mind a blending of identical and similar residua, so that one mental image is formed out of them; and the greater number of residua which have blended together to form the image, the more vivid will

be the perception and the more easily will it be revived; *classified perceptive knowledge is the result of the blending.*

Perception involves all the elements of logical thinking: "There are three operations (or states) of the mind which are immediately concerned in Argument; which are called by logical writers—1st, Simple-Apprehension; 2nd, Judgment; 3rd, Discourse or Reasoning.

"1st. Simple-Apprehension they define to be that act or condition of the mind in which it receives a notion of any object; and which is analogous to the perception of the senses. It is either Incomplex or Complex; Incomplex-apprehension is of one object, or of several without any *relation* being perceived between them, as of 'a man,' 'a horse,' 'cards'; Complex is of several *with* such a relation, as of 'a man on horseback,' 'a pack of cards.'

"2nd. Judgment is the comparing together in the mind of two of the notions (or ideas) which are the objects of apprehension, whether complex or incomplex, and pronouncing that they *agree* or *disagree* with each other: (or that one of them *belongs* or does not belong to the other.) Judgment, therefore, is either *affirmative* or *negative.*

"3rd. Reasoning (or 'discourse') is the act of proceeding from certain judgments to another *founded* upon them (or the result of them).

operations of the mind are not only expressed, and communicated to others, but even, for the most part, carried on by ourselves. The notion obtained in an act of *apprehension*, is called, when expressed in language, *a term*; an act of *judgment* is expressed by a *proposition*; an act of *reasoning* by an *argument*, which is made up of *three* propositions, and is called a syllogism" (Whately's "Logic").

When an object, on which the mind in its perceptive stage has been exercised, is removed, the mental image or impression retained of it is termed, not a *perception* but an *idea*. In the sound mind one idea, as all know by daily experience, is constantly displacing another, and thus a flow of ideas is constantly passing through the waking mind. Insanity occurs when one idea takes such complete possession that the mind is unable to entertain any other.* As the mind can only entertain one idea at a time, although it can pass with inconceivable rapidity from one to another, it follows that if two ideas are simultaneously presented to it, they will, if they are like or resemble each other, be by the law of similarity blended into each other, producing a more composite one. But if, by not being like, they cannot be blended,

* The new American puzzle, which is considered by many to be unsolvable, has, it is said, been the cause of at least one case of insanity: the idea of solving it gaining

the stronger of the two, for the *particular mind*, will cause the other to pass into the latent or unconscious state, thus becoming a residuum. All know the mind entertains an idea the more vividly the less it is occupied; hence it would appear that when one idea overcomes another, it loses a portion of its own power equivalent to that which it displaces. "Thus any new idea has very little effect upon the mind of a person who is deeply occupied in some absorbing subject or pursuit; the force it has to overcome ere it can command the consciousness *at all* is so great, that, by the time it comes up to the surface, its own effect is proportionally diminished. On the other hand, every one must have noticed the extreme sensibility which perfectly unoccupied persons usually have for trifling cares and annoyances, and the tendency of mental vacuity generally to produce hypochondriasis" (Morrell).

Ideas which cannot blend become associated if they have been brought into mental collision, the one having displaced the other from the conscious state; if no such action or reaction has taken place, then there can be no association between them—they stand wholly apart. It would be travelling beyond the bounds we have fixed for this part of our subject to enter upon the laws of association; suffice it to say that, objectively considered, they are by pretty general consent

admitted to be the following:—1. Similarity; 2. Contiguity in space; 3. Contiguity in time; 4. Logical affinity of the ideas; 5. The connection of cause and effect.

Before passing away from this part of our subject we must call attention to the terms *objective* and *subjective*, which have been, or will have to be, employed. We have learned that from objects all our sensations arise; therefore that part of our knowledge which we derive from the world external to us is termed *objective*, whilst that which belongs to our own minds is termed subjective. The late Dr. Whewell proposed the substitution of the word *ideal* for that of *subjective;* he considered the combination "*ideal* and *objective*" would more readily convey to a modern reader the opposition which is intended between the ideas of the mind itself, and the objects which it contemplates around it.

We employ language to convey our thoughts to others, and by means of it we learn the thoughts of others, but this is not the sole use of language; it is necessary for the progress of the mind's development to objectify our ideas, to project them quite out of ourselves, otherwise they would arise in the mind as confused in the waking as in the dreaming state. Outward signs have therefore to be employed to represent our ideas, and they become as much objects for the mind's contemplation

as the concrete ones; but they are something more than the latter; they are the embodiment of ideas, nature and idea being in them indissolubly united. Humboldt says: "Without perpetual transference of subject to object, and object to subject, which is accomplished only by language, no concept can be formed, and consequently *no thinking* is possible." And Dr. Whewell, in the quotation I have given (page 116), says: "Language is often called an instrument of thought; but it is also the nutriment of thought; or rather, it is the atmosphere in which thought lives." "While engaged" (says M. Lavoisier) "in the composition of my Elements of Chemistry, I perceived, better than I had ever done before, the truth of an observation of Condillac—that we think only through the medium of words; and that languages are true analytical methods. Algebra, which of all our modes of expression is the most simple, the most exact, and the best adapted for its purpose, is at the same time a language, and an analytical method."

In the infancy of all nations, as in that of the individual, the objective representation of ideas takes the form of pictorial symbols, and even when the intellect of a nation has become so far matured that the sciences begin to be cultivated, pictorial representations have been employed; and even after they have advanced, and new ideas arise, that

form of representation has been resorted to. This is well illustrated in the history of the science of Chemistry. Curious pictorial tables appear in works on that science at an early date, as in the "Dissertation on Electric Affinity," by Bergmann, which was first published in the year 1775; and when Dalton first propounded the atomic theory, pictorial representations of the theory were given in some books on the science; and still more recently, "graphic notation" has been resorted to with the object of picturing the arrangement of the individual atoms of a chemical compound. But as the intellect advances arbitrary signs begin to be substituted for the more symbolic ones; and they represent, not the things themselves, but the mental image we have formed of them. Locke says: "We bring unavoidable confusion and obscurity into the signification of words whenever we make them stand for anything but those *ideas* we have in our own minds."*

* "But the great glory of the Phœnicians, and the plainest mark of their early civilization, *is their invention of alphabetic writing.* Other nations — notably the Egyptians and Babylonians—had anticipated them in the invention of a method whereby articulate sounds were represented to the eye by forms and figures. But the systems which these nations introduced and employed were not alphabetic; they were cumbrous and complicated, unapt for ordinary or extensive use, and such as to require for their mastery a special and almost professional training. Both employed a large number of *ideographs*, or signs of ideas; both used numerous *determinatives*, signs prefixed to a word, or added after it; both had a redundancy

Dr. Whewell has well remarked that language is the atmosphere in which thought lives, for there is hardly a subject we can think about without the aid of language—consequently, without a knowledge of the language of a science all thinking with regard to that science is impossible; for although we *perceive* the world by means of our senses, we *comprehend* it only in and through the forms of language. A mere knowledge of individual words

sometimes in one, sometimes in another manner. In one respect the Babylonian and Egyptian methods differed, and the latter approached to the verge of being an alphabetic system. The Babylonian characters did not represent the elementary sounds of human articulation, but stood for complete syllables, for a consonant with a vowel, either before or after, or for the combination of two consonants with a vowel between them. The Egyptians proceeded beyond this; they went so far as to decompose the syllable, and possessed signs which were 'letters' in the exact modern sense. But they never wrote with these signs exclusively. Their system was from first to last a jumble, in which symbolic and determinative signs were mixed up with phonetic ones, and in which the phonetic ones were of two classes, alphabetic and syllabic; in which, moreover, the ideographic signs might take an accidental phonetic value at the commencement of certain words, and the alphabetic and syllabic characters might also be employed ideographically. It was left for the Phœnicians to seize on the one feature of Egyptian writing, which was capable of universal application, to disentangle it from the confused jumble of heterogeneous principles with which it was bound up, and to form a system of writing in which there should be no intermixture of any other method. To do this work was to take a step in advance greater than any which had been previously taken; it was, it has been well said, to 'consummate the union of the written and spoken word, to emancipate once for all the spirit of man from the swaddling-clothes of primitive symbolism, and to allow it at length to

in a language is not sufficient; for "words, individually considered, do not make a language. Language involves the further power of *combining words together*, so as to express not merely isolated notions, but the various *relations*, which these notions bear to each other. Such a power is evidently higher in the scale of intellectual development than that of merely constructing individual signs. In the latter case, we are only

worthy of it; perfect in respect of clearness, of elasticity, and of convenience for use.'

"The complicated and cumbrous systems of the Babylonians and Egyptians could never have become general or have been of any great service to mankind. The method adopted by the Phœnicians rapidly proved its excellence by showing itself fruitful and overspreading the earth. It is one of the chief marks of genius to see to the roots of things, to discern the one in the many, and to grasp the *simple* principle, which is alone of universal applicability. This mark of genius the Phœnicians showed. The form of writing which, according to a universal tradition, was invented by them, possessed the quality of simplicity in perfection, and was no sooner discovered than it began to spread. Adopted readily by the neighbouring nations, it was soon carried far and wide over the Asiatic continent, and under slightly modified forms is found to have been in use from the shores of the Indian Ocean to those of the Euxine, and from the Ægean to the remotest parts of Hindostan. Nor was it content with these conquests. It crossed the sea which separates Asia from Europe, was carried to Crete, to Thera, to Greece, to Sicily, to Italy, and to Spain. It also made a lodgment on the African seaboard, and ere many centuries were gone by, prevailed from the borders of Egypt to the Atlantic Ocean. Accepted by the two greatest peoples of antiquity—the Greeks and Romans—it passed from them to the nations of Northern Europe, and has thus become the system of almost the whole civilized world."—Professor GEORGE RAWLINSON on *The Origin o Nations*

engaged in the work of *representation* (representation, it is true, in its most complete form); but in the former case we are judging *explicitly* between one representation and another, and framing a method by which such judgments may be afterwards articulately expressed. It is exactly here, accordingly, that the power of representation passes over into the distinctive sphere of *thought.*"*

We shall have to call attention to this question of language when we discuss the methods adopted for teaching Chemistry; but before passing away from the subject, we may notice that language is misused, or rather abused, when we employ it as the representation of THINGS external to us, as well as the THOUGHTS we think about them; this is done when language, whether written or spoken, is employed as the sole medium for acquiring a knowledge of such sciences as Chemistry, Geology, Botany, &c., instead of learning or teaching them

* "Language, we must remember, is not constructed afresh by every individual mind which uses it. It is a world already created for us, one into which we have simply to be *introduced*, and in which the process of human development, up to any given period, is more or less perfectly preserved and registered. Recollection, accordingly, by enabling us to appropriate to ourselves a whole system of signs with the ideas attached to them, initiates us insensibly into the intellectual world of the present, puts us upon the vantage-ground of the latest degree of civilization, and enables us to grasp the ideas of the age without having the labour of thinking them out consecutively, by our own individual effort."—*Elements of Psychology*, by Dr. MORRELL.

by experiment and observation on the things around us.*

In connection with the representation of our

* "One obvious mode of effecting this discipline of the mind in induction is the exact and solid study of some portion of inductive knowledge. I do not mean the mechanical sciences alone, Physical Astronomy and the like; though these undoubtedly have a prerogative value as the instruments of such a culture; but the like effects will be promoted by the exact and solid study of any portion of the circle of the natural sciences—Botany, Comparative Anatomy, Geology, Chemistry, for instance. But I say, the *exact* and *solid* knowledge: not a mere *verbal* knowledge, *but a knowledge which is real in its character*, though it may be elementary and limited in its extent. The knowledge of which I speak *must be* a knowledge of things, and *not merely* of *names* of things; an acquaintance with the operations and productions of Nature, as they appear to the eye, not merely an acquaintance with what has been said about them."—Dr. WHEWELL on *The Scientific History of Education.*

"Men marvel at the absurdity of other people's tenets, while exactly parallel absurdities remain in their own. And the same man is unaffectedly astonished that words can be mistaken for things, who is treating other words as if they were things, every time he opens his mouth to discuss. No one, unless entirely ignorant of the history of thought, will deny that the making of abstractions for realities pervaded speculation all through antiquity and the Middle Ages. The mistake was generalized and systematized in the famous ideas of Plato. The Aristotelians carried it on. Essences, quiddities, virtues residing in things, were accepted as a *bonâ fide* explanation of phenomena. Not only abstract qualities, but the concrete names of genera and species, were mistaken for objective existences. It was believed that there were general substances corresponding to all the familiar classes of concrete things; a substance Man, a substance Tree, a substance Animal, which, and not the individual objects so called, were directly denoted by those names. The real existence of universal substances was the question at issue in the famous controversy of the later Middle Ages between Nominalism and Realism, which is one of the turning-points in the history of thought, being its first struggle to emancipate itself from the dominion of verbal abstractions."—*Auguste Comte and Positivism*, by JOHN STUART MILL.

ideas by means of language is the reproduction of our ideas by means of the memory; this is not meant to imply that the memory does not come early into play in the mind's life, but that it stands to ideas as attention does to perceptions.* The awakening up in the mind of ideas that have been dormant, sometimes for a very long time, is brought about by the recurrence to the mind of other ideas with which the one in question had become asso-

* Curiosity is as much the parent of attention as attention is of memory; therefore the first business of a teacher—first, not only in point of time, but of importance—should be to excite, not merely a general curiosity on the subject of the study, but a particular curiosity on particular points in that subject. *To teach one who has no curiosity to learn, is to sow a field without ploughing it. And this process saves a student from being* (as many are) *intellectually damaged by having a very good memory. For an unskilful teacher is content to put before his pupils what they have to learn, and ascertaining that they remember it; and thus those of them whose memory is ready and retentive, have their mind left in a merely passive state, and are like a person always carried about in a sedan chair, till he has almost lost the use of his limbs. And then it is made a wonder that a person who has been so well taught, and who was so quick in learning and remembering, should not prove an able man; which is about as reasonable as to expect that a capacious cistern, if filled, should be converted into a perennial fountain.* Many are saved, by the deficiency of their memory, from being spoiled by their education; for, those who have no extraordinary memory are driven to supply its defects by *thinking*. If they do not remember a mathematical demonstration, they are driven to devise one. If they do not exactly retain what Aristotle or Smith have said, they are driven to consider what they were *likely* to have said, or ought to have said. And thus their faculties are invigorated by exercise. Now, this kind of exercise a skilful teacher will afford to *all*; so that no one shall be spoiled by the goodness of his memory."—*Annotations on Bacon's Essay "Of*

ciated when in the conscious state, and the more complete the order of the arrangement, classification, and connection of our ideas, the more readily will we reproduce every idea which has passed into the latent state. "The power of memory may be represented to us," Dr. Morrell states, "under the figure of a spider's web, which sends out its threads in all directions, establishing connection with every part, and with the central point of the whole. When the mind has woven such a web around any object, it can pass along any of the threads at pleasure, and reach any given point in the system. Thus it only depends on *volition* to keep the clue to every idea we may require to recall in our minds, and to bring it at any moment back into the light of consciousness."*

Those who have not given any study to the operations of the memory regard it as a simple

* "Now, it is obviously upon this recording of impressions, so that they are reproduced as Ideas when the appropriate *suggesting strings* are pulled, that all our accumulated knowledge depends. For when we say that we 'know' a language, or an author, or a department of science, we do not mean that the whole or even any part of that knowledge is present to our minds at the time; since, as Sir William Hamilton has justly remarked, 'the infinitely greater part of our spiritual treasures lies always beyond the sphere of our consciousness.' The perfection of our knowledge consists, in fact, in the readiness and precision with which the appropriate words or ideas *spontaneously* present themselves, whenever we *desire* to bring them *within* the sphere of our consciousness; and this action depends upon the strength of the association previously formed between the word or idea actually before the mind at each moment, and that which furnishes the response to it. Thus, in

mental act. The expression good or bad memory in ordinary language indicates that this is the popular view of it; but it will scarcely have eluded the observation of any one, that persons very frequently display an excellent memory for things connected with the pursuits in which they are engaged, who have no memory for things or terms unconnected with those pursuits: thus a broker will tell you not only what was the price of any article—say tallow—for which he is a *conveyancer*, a month ago, but he will tell you readily what it was twelve months ago; and yet the same person will be incapable of remembering scientific terms or phrases which have been told him, because there are no analogous ideas in his mind which would form natural links of connection for their reproduction. I have in my experience met with only one exception to the rule. Some years ago I became

speaking a foreign language with which we are thoroughly conversant, the *automatic* play of suggestion calls up the successive words or phrases that express the equivalents of those in which our thoughts have shaped themselves. In quoting a book with which we are familiar, the sequence of a long passage may be suggested by the mention of its first words, or by the starting of the idea that forms the subject of it. And when the man of science is called upon to 'explain' a fact, his mind goes forth, as it were, in the direction most likely to lead to the recall of similar facts which he has previously learned, and to that of some principle common to them all. On the other hand, we say that we have 'forgotten' a word or an idea, when we are conscious of the fact that we *must* have once known it, but cannot reproduce it at the moment."—*Mental Physiology*, by Dr. CARPENTER.

acquainted with a gentleman who could recollect scientific terms and phrases, and descriptions of chemical operations, although completely ignorant of any science; but they were always those in which his own self-interest was concerned. All the different artificial memory systems are based on the plan of employing non-natural (artificial) links to bind together ideas whether analogous or non-analogous.

It ought never to be overlooked, either by the educator or the educated, that memory is not a simple but a complex mental operation, and that the thorough apprehension of what is learned is a slow process; for what is rapidly learned—that is, merely "committed to memory"—is very commonly forgotten as quickly, "one set of ideas driving out another." The late Lord St. Leonards being asked what was the secret of his success, replied: "I resolved, when beginning to read law, to make everything I acquired *perfectly my own*, and never to go to a second thing till I had entirely accomplished the first. Many of my competitors read as much in a day as I read in a week; but at the end of twelve months my knowledge was as fresh as on the day it was acquired, whilst theirs had glided away from their recollection."

The mind, like the body, experiences fatigue from exertion: this is attributed to the brain-tissue becoming worn out by the exercise. A period of

repose is therefore required to renovate the tissue so that the mind may become re-invigorated.

"I descended," Sir H. Holland states, "on the same day two very deep mines in the Hartz mountains, remaining some hours underground in each. While in the second mine, and exhausted both from fatigue and inanition, I felt the utter impossibility of talking longer with the German inspector who accompanied me. Every German word and phrase deserted my recollection; and it was not until I had taken food and wine, and been some time at rest, that I regained them again."

Time, as illustrated in Lord St. Leonards' case, is required for registering ideas thoroughly in the mind; and the reason why we remember well in the morning what has engaged our attention just prior to going to sleep, is due, no doubt, to the same cause;* and although it may not appear quite so obvious, it is due, no doubt, to the agency of time, that, after wearying the mind over some

* Lord Macaulay, in his Essay on "The Comic Dramatists of the Restoration," says "that Wycherley's memory played him pranks stranger than almost any that are to be found in the history of that strange faculty. It seemed to be at once preternaturally strong and preternaturally weak. If a book was read to him before he went to bed, he would wake in the morning with his mind full of the thoughts and expressions which he had heard over night; and he would write them down, without in the least suspecting that they were not his own. In his verses the same ideas, and even the same words, came over and over again in a short

difficulty, we leave it unsolved, and return to the subject the next day, it is easily overcome.

It is continually overlooked in the work of instruction that time is required for registering ideas thoroughly in the mind, and that the over-crowding of ideas into the mind in a given time, especially if the subject is one which the learner is only beginning to study, is most fatal to real progress; and to this cause I attribute much of the aversion which most children early display to learning.

It is very rarely attention is paid by teachers to the necessity of *time* for the forming of *permanent* impressions on the brain; beginners are too frequently kept at their studies for as long a time as the more advanced students. Even cultivated minds cannot work for the same length of time at a new study as they can at one they have longer cultivated, the mind becoming sooner fatigued with the new than the old study; just as any one commencing any new bodily exercise, becomes sooner fatigued with it than those he has been longer accustomed to.*

* "Many persons will forget in no very long time every word of a language which they have once spoken fluently, or of a matter with which they have been thoroughly conversant. Hence a good Assimilative Memory indicates vigour of brain, and also a power of steady application, for it does not yield its harvest in the way of a new practical capacity without long-continued culture. 'Lightly come, lightly go' holds of learning as of other things; and

In a former Lecture I stated I would point out to the Teacher what he had to guard against in those Students who appear at once to comprehend the subject that is being taught; it is owing, in the majority of cases, to the facility many persons have of remembering mere words, without in the least understanding or comprehending their meaning—that is, the ideas they represent.

Words are always more easily remembered than *things*, our thoughts being much more conversant with them than with the latter; consequently we are too apt to assent to propositions to accept statements, and believe we understand a subject; whilst we only remember the *mere words*, which are but the outward covering.

When we come to deal with written examinations as tests of the knowledge Students have acquired of any experimental science, we shall

what is rapidly learned is rapidly lost, unless it be impressed on the mind in some unusually vivid way. A man cannot by working eight hours a day at Greek or Algebra get twice as much facility in dealing with them as if he worked four hours. Assimilation cannot be hurried; the mind will only absorb at a certain rate. The amount of a *book* which can be 'got up' for production is much more nearly proportional to the time spent on it; but such knowledge soon passes away, because it is not taken into the system. Dr. Carpenter tells a story of an actor who, having once had to learn a part in a hurry, forgot it altogether soon after he had played it, and had to learn it afresh afterwards whenever he had to act it, although the parts which he had studied at leisure remained always by him ready to be performed when wanted. These he had *assimilated* the other he only *carried*.—*On the Action of Examinations*, by HENRY LATHAM.

show how this mere memory for words can and is made use of, and how fallacious written examinations are as tests of true knowledge in those sciences.

The mind is constantly occupied with its *perceptions* or its *ideas* in every stage of its advancement; and the mental representations or impressions of the things of the objective world become more idealized in each ascending stage, and as idealization increases the power of reproducing ideas assumes new and more advanced forms. One of these forms is termed *imagination;* in its lowest stage it is *reproductive* or *constructive*, in its highest stage it is *productive* or *creative.* The difference between mere memory and constructive imagination may be not altogether inaptly illustrated by a photograph and a highly artistic portrait: in the one there is a correct likeness as regards the facial expressions at the moment the photograph was taken; the other represents not one set of expressions, but a general expression of the every-varying ones of the countenance combined into one harmonious whole, and idealized to the extreme limit of artistic perfection. In like manner, constructive imagination gives a less particularized copy than mere memory does of the object; the mental image it portrays is a more idealized one, and these more idealized images are types by which we compare any new phenomena

we meet with, and there thus begins the work of reducing to *unity* our experiences.

Professor Dugald Stewart, in his "Philosophy of the Human Mind," remarks, "That creative imagination is not an original endowment of the mind, but an accomplishment formed by experience and situation, and which, in its different gradations, fills up all the interval between the first efforts of untutored genius and the sublime creations of Raphael or of Milton." I think this power of the mind is more correctly described by Dr. Carpenter. He says, "The exercise of the *creative* imagination involves that peculiar quality of mind which we distinguish as Genius;—a special gift of which no definite account can be given, the possessor of it not being himself able either to trace its origin, or to describe (save as regards its external conditions) its mode of working. Although this term is often applied to superior intellectual power of *any* kind, yet it may certainly be most appropriately limited to that of which *invention*, *origination*, or *insight*, is the distinctive characteristic, and of which the products bear the well-marked stamp of *individuality*. Working upon the materials it derives from observation and reflection, Creative genius not merely develops and recombines these, but evolves products *altogether new*, beyond the scope of the reasoning power, and deriving their value from their expression of a

higher truth than is at the time attainable in any other way." Dr. Channing observes, "That genius is not a creator in the sense of fancying or feigning what does not exist; *its distinction is, to discern more of truth than ordinary minds.*" Newton, for instance, discerned more truth than Kepler and other great discoverers. It is a very limited view of the imagination, Dr. Carpenter remarks, "To regard its operation as restricted to works of art, of which the object is to gratify the æsthetic sense, for its highest exercise is put forth in the discovery of great fundamental truths, as well in science as in art, in the universe around us as in the mind of man."

The next stage of the mind's development constitutes what are termed the *logical processes*; the same laws govern the mind in this as in the preceding stages, no new or distinct faculty being developed; yet many minds cannot ascend to this higher stage, in which knowledge begins to be organized; they here stop short in their growth, and hardly attain any degree of logical power whatever beyond that instinctive logic which is involved in all the lower forms of our intellectual activity.* Mr. Herbert Spencer,

* "In what consists the principal and most characteristic difference between one human intellect and another? In their ability to judge correctly of evidence. Our direct perceptions of truth are so limited; we know so few things by immediate intuition—or, as it used to be called, by simple apprehension—that we depend

in his "Principles of Physicology," vol. i., gives some very apposite illustrations and valuable observations on this most important part of the subject :—"For scientific and artistic progress is due not simply to the accumulation of knowledge and of appliances; the impressibilities and the activities have themselves grown to higher complications. There is evidence from various quarters that the minds of the inferior human races cannot respond to relations of even moderate complexity; much less to those highly-complex relations with which advanced science deals. According to the traveller Lieutenant Walpole, it is remarked of the Sandwich Islanders, by their teachers, 'that in all the early parts of their education, they are exceedingly quick, but not in the higher branches; that they have excellent memories, and learn by rote with wonderful

for almost all our valuable knowledge, on evidence external to itself; and most of us are very unsafe hands at estimating evidence, where an appeal cannot be made to actual eyesight. The intellectual part of our education has nothing more important to do, than to correct or mitigate this almost universal infirmity—this summary and substance of nearly all purely intellectual weakness. To do this with effect needs all the resources which the most perfect system of intellectual training can command. Those resources, as every teacher knows, are but of three kinds—first, models; secondly, rules; thirdly, appropriate practice. The models of the art of estimating evidence are furnished by science; the rules are suggested by science; and the study of science is the most fundamental portion of the practice.—The late JOHN STUART MILL.

rapidity, but will not exercise their thinking faculties.' That is to say, they can readily receive simple ideas, but not complex ones. Again, of the Australians we read that 'some of them are very quick at acquiring knowledge, but they have no power of combination or concentration.' The reports of Hindoo schools disclose, though in a less marked manner, the same fact. One of the reasons assigned in the United States for not educating negro children along with white children, has been that after a certain age they 'do not correspondingly advance in learning—their intellects being apparently incapable of being cultured beyond a particular point.' And this statement, which might else be suspected of bias, agrees with that made respecting the same race in Africa by Sir Samuel Baker, who says: 'In childhood I believe the negro to be in advance, in intellectual quickness, of the white child of a similar age, but the mind does not expand—it promises fruit, but does not ripen.' So, too, of the Andaman children we read that they 'catch up words readily and repeat them, but seem incapable of connecting words with corresponding ideas.' Even the finest uncivilized races show us the like limitation. 'Without genius for discovery, and incapable of generalizing,' the New Zealanders 'are nevertheless apt at acquiring the rudiments of learning'; . . . 'boys at ten years

as a rule, few New Zealanders could be taught to equal Englishmen in their highest faculties.' In all these cases, as also in the minor cases continually occurring among ourselves of inability to understand reasonings passing a certain degree of abstruseness, the interpretation is that the intellect has not reached a complexity equal to the complexity of the relations to be perceived. Not only with purely intellectual cognitions does this hold; it holds also with what we distinguish as moral cognitions. In the Australian language there are no words answering to justice, sin, guilt. Among most of the lower races, acts of generosity or mercy are incomprehensible. That is to say, the more involved relations of human actions in their social bearings are not cognisable. We must, therefore, conclude that the complex manifestations, intellectual and moral, which distinguish the large-brained European from the small-brained savage, have been step by step made possible by successive complications of faculty."

It has been already stated (page 157) that there are three operations (or states) of the mind which are called by logical writers—(1) Simple Apprehension; (2) Judgment; (3) Discourse or Reasoning.

The names of "Objects of Thought" are called, as already stated, in logical language, terms. A name which denotes one object, considered as an individual existence, is called a *singular term*. A

name—such, for example, as the word metal, which is applicable in the same sense equally to *any one* of an indefinite number of objects which resemble each other in certain qualities—is called a *general term*. The name of a thing or object, as red rose, is called a *concrete term*; the name of a quality, attribute, or circumstance of a thing, is called an *abstract term*; red, for instance, is one quality of the rose.

"The process by which the mind arrives at the notions expressed by *general terms* is properly called 'Generalization,' though it is usually (and truly) said to be the business of *Abstraction*;* for Generalization is one of the purposes to which Abstraction is applied. When we *draw off*, and *contemplate separately*, any part of an object presented to the mind, disregarding the rest of it, we are said to *abstract* that part. Thus, a person might, when a rose was before his eyes or mind,

* Archbishop Thomson describes Abstraction as a process of five acts:—1. *Comparison* is the act of putting together two or more single objects with a view to ascertain how far they resemble each other. 2. *Reflection* is ascertainment of their points of resemblance and their points of difference. 3. *Abstraction* is the separation of the points of agreement from those of difference, that they may constitute a new nature different from, yet including, the single objects. 4. *Generalization* (without which, the Archbishop states, there can be no abstraction) is the recognition of a class of things, each of which is found to possess the abstracted marks. 5. *Denomination* is the imposition of a name that shall serve to recall equally the Genius or Class and the Common Nature.

make the scent a distinct object of attention, laying aside all thought of the colour, form, &c.; and thus, even though it were the *only* rose he had ever met with, he would be employing the faculty of Abstraction; but if, in contemplating *several* objects, and finding that they agree in certain points, we abstract the circumstances of agreement, disregarding the differences, and give to all and each of these objects a name applicable to them in respect of this agreement—*i.e.*, a general name or term, as 'rose'—or again, if we give a name to some attribute wherein they agree, as 'fragrance' or 'redness,' we are then said to *generalize*. Abstraction, therefore, does not necessarily imply Generalization, though Generalization implies Abstraction. The notion expressed by a general term is merely an inadequate (incomplete) notion of an Individual, and from the very circumstance of its inadequacy, it will apply equally well to any one of an indefinite number of individuals of the same description—to any one, in short, possessing the attribute or attributes that have been abstracted, and which are designated by that general term" (Whately).

The act or condition of the mind in which it receives a notion of an object is designated by the expression "Simple Apprehension," and the mental fact, which corresponds with the term employed by logicians, has sometimes been

expressed by the word *notion*, sometimes by the term *abstract idea*, but more generally by the word *concept*.

JUDGMENT, the next in order of the logical processes, is the *comparing* together two notions (or ideas) of objects derived from simple apprehension, so as to ascertain whether they *agree* or whether they differ (or that one of them *belongs* or does *not* belong to the other). Judgment, therefore, is either *affirmative* or *negative*. It is, consequently, *by separating* and *distinguishing* that all judgment is carried on.* Examples:—Iron is a metal; sulphur is not a metal; all metals are elements; some metals are brittle.

In explaining the third of the logical processes, usually denominated *reasoning*, it will be desirable to direct attention, in the first instance, to the

* "I imagine we should neither of us care to go into metaphysical subtleties about this mental act of choice. Passion, habit, intellect, are all blended in what we popularly call a choice. But it is really choice only so far as the intellect or judgment is concerned. Choice in the most complex affairs of life is still a development of that faculty of judgment or comparison (perception of difference or agreement) which philosophers of all schools agree in placing amongst the original powers of the human being. Of two propositions we say, this or that may be true. Of two proposed actions we say, this or that may be done. The latter of these states of mind is as indisputable a fact as the former. In both the intellectual act of judgment is performed, though in the latter it is more complicated with our individual susceptibilities and emotions. In the one we have to select a truth, in the other to choose a conduct. We choose. A judgment is finally pronounced."—*Gravenhurst; or, Thoughts on Good and Evil*, by WILLIAM SMITH.

two kinds of truths—viz., the *necessary* and the *contingent.* The former kind are truths which cannot but be true; as six and six make twelve. They are independent of experiment and observation. "The latter are truths which it *happens* (*contingit*) are true; but which, for anything which we can see, might have been otherwise; as that a lunar month contains thirty days, or that the stars revolve in circles round the pole. The latter kind of truths are learnt by experience, and hence we may call them *Truths of Experience,* or, for the sake of convenience, *Experiential* Truths, in contrast with Necessary Truths. We see these last to be true by thinking about them, and see that they could not be otherwise; they are derived from our own thoughts. Experiential truths we could never have discovered to be true without looking at them, and having so discovered them, still no one will pretend to say they may not have been otherwise; they are derived from our observation of things about us. General experiential truths are called *theories,* and the particular observations from which they are collected, and which they include and explain, are called *facts.* A true theory is a fact; a fact is a familiar theory" (Whewell).

The truths of Geometry, which are necessary truths, are established by demonstrations *deduced* from definitions and axioms.

With regard to experiential truths, we proceed, by what is termed an *Inductive Process*, from the observation of external things to the discovery of general truths which include them.

From what has been stated with regard to the two kinds of truths, it will be seen that there must be at least two kinds or modes of reasoning —viz., *deductive* and *inductive;* these two modes we will now proceed to consider.

We reason *deductively* when we deduce effects from causes; particular truths from more general ones. We shall see presently that no new truths can be elicited by this process of reasoning. Deduction in Logic is resolved into the formula called the *syllogism.* Every legitimate syllogism contains three, and only three, propositions—namely, the proposition to be proved, which is called the *conclusion* or *inference;* and two other propositions, which together prove it, and which are called the *premises.* One is termed the *major* and the other the *minor* premise; the former, the major, always stands before the latter in strictly correct syllogisms. A syllogism is also composed of *three terms,* and the reasoning consists in comparing two of them with each other by means of the third, which is called the *middle term.* The middle term *must be distributed*—that is, *taken universally, or in its whole extent of meaning, once at least* in the premises. Example:—

All metals are elements.
Silver is a metal.
Therefore Silver is an element.

It will be observed that no new truth is elicited in this syllogism: in the major premise it is stated that *all* metals are elements; therefore what is true of the entire class must be equally true of any one of the class. The late Archbishop Whately thus expresses it in his "Logic":—"Since all reasoning (deductive) may be resolved into syllogisms, and since in a syllogism the premises do virtually assert the conclusion, it follows at once that no new truth can be elicited by any process of reasoning." By deductive reasoning, therefore, we can only add to our knowledge of effects, not to our knowledge of causes. "It is confessed on all hands that all which the deductive sciences, mathematics and logic, can do is to develop and extract those truths which were in reality involved in the principles on which our reasonings proceeded. And this being allowed, we cannot but ask how we obtain those principles? from what other source of knowledge we derive the original truths which we thus pursue into detail? since it is manifest that such principles cannot be derived from the proper stores of mathematics and logic. These methods can generate no new truth; and all the grounds and elements of the knowledge which, through them, we can acquire, must neces-

sarily come from some extraneous source." It is, therefore, certain that we must derive the substance and material of our knowledge from some process different from those of the mathematician and the logician.

By observation and experiment we become acquainted with facts which form the basis of our knowledge of the external world, and by the process of induction we ascend from particular facts to the discovery of the general laws and principles by which they are governed and united ; it is by the inductive process, which may be defined as generalization from experience, that *all our knowledge of Nature* is obtained.

Bacon was not the author of the Philosophy of Induction, but it was he who first brought it prominently forward, and insisted that it was the only true and correct method of scientific inquiry ; he further insisted upon a *graduated and successive induction*, as opposed to a hasty transit from special facts to the highest generalizations. "There are two ways," he says, "and can only be two, of seeking and finding truth. The one, from sense and particulars, takes a flight to the most general axioms, and, from those principles and their truth, settled once for all, invents and judges of intermediate axioms. The other method collects axioms from sense and particulars, ascending *continuously and by degrees*, so that in the end it

arrives at the most general axioms. This latter way," he most correctly observes, "is the true one, but hitherto untried." He elsewhere speaks in his works of the successive *floors* of induction, and speaks of each science as a *pyramid* which has observation and experience for its basis.

Those sciences which are concerned about the material world are inductive sciences; but although this is the case, "by far the greater part of our books on physical science unavoidably consist in *deductive* reasoning, exhibiting the consequences and applications of the laws which have been discovered; and the greater part of the writers upon science have their minds employed in this process of deduction and application."

In inductive reasoning we reason *upwards*, as it were, from particular instances to general conclusions; in deductive reasoning we reason downwards, as it were, from general propositions to particular instances. It will be apparent to any one that a different mental cultivation and training are necessary for the two modes of reasoning; hence, it not unfrequently occurs that those who have exclusively confined themselves for some time to studies which embrace only one of these modes of reasoning, become mentally unfit for the successful prosecution of studies which require for their cultivation the other and opposite mode of reasoning. This has been too frequently neglected in

general education, when our minds ought to be completely and efficiently cultivated, which cannot be if studies which involve only one of the modes of reasoning are alone taught. We shall, as we proceed, again direct the attention of the reader to this important subject.

We first acquire by experience a knowledge of Nature and its laws, and the knowledge so acquired is obtained either by observation or experiment. By the first method we simply observe what, without our aid or interference in any way, takes place in the natural world. In order to observe correctly, we must not allow our feelings, prejudices, wishes, or preconceived opinions of any kind to influence our observations; and this is by no means so easy a task as might be supposed; it is on account of the difficulty of observing correctly that little or no reliance can be placed upon the supposed observations of uncultivated observers. The mind of man, Bacon states, is like an uneven mirror, and does not reflect the events of Nature without distortion.

By experiment we interfere with the natural order of things, by subjecting substances individually, or two or more of them, which we have brought together, to conditions other than those we have seen them subjected to in Nature; and observing and recording the changes, if any, that are produced on the substances so operated upon.

states Sir John Herschell, and they may be properly be called *passive* and *active* observation. In the former mode, he states, "we sit, as it were, and listen to a tale told us, perhaps obscurely, piecemeal, and at long intervals of time. In the latter, we cross-examine our witness and compare one part of his evidence with another, while he is yet before us; and reasoning upon it in his presence, we are enabled to put pointed and searching questions, the answers to which may enable us to deduce intelligible and correct conclusions."

In briefly noticing the highest stage of mental development, we will commence by bringing again under review the three fundamental forms of intellectual activity we have already noticed :—(1) Perception ; (2) Ideation ; (3) Logical Thinking. In the first stage the mind is occupied on some *object out of itself* ; in the third stage it is so occupied, on the contrary, in the construction and contemplation of *defined* forms of thought, that it loses sight of the *matter*, and moves in a world of pure abstractions and relations. In the first stage, the universe is contemplated without any accompanying consciousness of mind, as the subject ; in the other stage, our own mental images are contemplated as though they were equivalent to the universe. "The result in both cases is equally incomplete, and a further development of our intellectual being is manifestly necessary in order to

unite the results of both these previous efforts into a higher and more perfect unity. Let us consider in what way this development takes place.

"The mind, now become perfectly *free* in its intellectual activity, looks back upon all the other processes of knowledge through which it has passed with a comprehensive and penetrating glance. It can either bring over the *direct* knowledge, which it has gained by means of its intuitions, into the forms of the understanding; or, on the other hand, it can begin with accepting the forms of the understanding as valid for all truth, and then seek voluntarily to *fill* them out with real concrete experience. In this way we come to view mind and Nature as being, at the root, *counterparts* of each other; and proceeding upon this tacit assumption, we use all the power of generalization we have acquired by the understanding, to strip away what is merely temporary, in the multiplicity of our daily experiences, and to retain that which bears upon it the marks of a *universal truth*, valid alike in the sphere of Nature and in the region of thought.

"The knowledge thus gained will be manifestly higher in the scale of human development than that either of perception or of understanding. It contains the reality of the one, the ideality of the other; the depth of the one, the distinctness of the other; it gathers up, in fine, all the fruits of our entire mental history, and combines them into a

new and superior unity of knowledge, which, when duly carried out, we designate by the term *science.*

"The proper function of REASON, then, is to create knowledge, which shall be at once *real* and *universal*—*i.e.*, to create *science.*

"Science, however, is not all stamped with the same precise characters; it may have a larger or a smaller amount of direct experience in it, as well a larger or smaller amount of pure intellectual activity. Reason, therefore, like all the other faculties, will show a regular progression, in which freedom of action, and the power of self-determination, increase with every ascending step. These steps we must now attempt to characterize.

First Step.—Observation and Experiment.

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Second Step.—Reflection.

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Third Step.—Speculative Thinking.

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"The process of reason, then, may be described, in conclusion, as a perpetual progress from the real to the ideal, and from the ideal back again to the real; at each step becoming more replete with higher thoughts of truth and existence."*

* "Elements of Psychology," by J. D. Morrell, LL.D. I would strongly recommend the young student who is studying the inductive sciences to study this work by Dr. Morrell, and he will find it a good introduction to the larger work, "An Introduction to Mental Philosophy," by the same author; or to the works of Professor Bain or Mr. Herbert Spencer on the same subject.

LECTURE V.

This Lecture devoted to the Teaching of Elementary Chemistry —No Distinction hitherto made in the Teaching of the Science in Secondary Schools and in Colleges—The Distinction to be made—Descartes and others on the Laws and Regulative Principles of Education—The same Plan followed in the Construction of Reference and Educational Works on the Science—The Plan unsuitable for Teaching the Elements of the Science—The Uneducated Workman in a Chemical Factory and the Lecture-taught or Book-taught Student contrasted—The Teacher and the Book—The Philosophy of Science—The Origin of Lectures—Only Two Ways of Seeking and Finding Truth—The Teaching by Lectures and Books not in Harmony with the Baconian Method—The Difficulty the Mind experiences in organizing Knowledge illustrated—The Difficulty of judging correctly of Evidence —How Elementary Chemistry is Taught, shown by Examples—Not Taught in accordance with the Laws of Thought; the Science thus rendered an Inefficient Instrument for Training the Mind—Imperfect also in Teaching the Science—Objections to its Study on this account—Disadvantages in employing complicated Apparatus in Teaching—A Method more in harmony with the Laws of Thought than the one at present in use described—The Neglect in Describing the Conditions under which Chemical Changes take place, renders the Science more Empirical than it would otherwise be, and Retards its Advancement, illustrated.

THIS Lecture will be confined almost entirely to the consideration of the *methods* for the teaching of Elementary Chemistry. In discussing the methods

of teaching, it will conduce very much to precision if the line of separation to be recommended between the teaching of the Science in the Secondary Schools* and in Colleges and Universities be first stated. The correct and rational line of demarcation I believe to be, that the teaching in Colleges and Universities ought to be restricted to the teaching of the *highest* branches *solely* of acquired knowledge, the *highest* branches of Analysis, and Original Investigations, with the addition, in Technical Colleges, of the Applications of the Science. The teaching in the secondary schools ought to be restricted to the teaching of the conditions under which chemical changes take place, qualitative and volumetric analysis; and the instruction ought to be mainly practical.

No distinction in teaching this science in our Schools and Colleges has hitherto been observed, to the great injury of the teaching in both. If any of my readers were to enter the chemical lecture-room of any of the Colleges at Cambridge, Oxford, or elsewhere, say at the beginning of a session, and he were then to visit the chemical lecture-room of some Secondary School, and heard

* The term Primary Schools is usually restricted to those schools in which only the mother tongue and the simplest and indispensible branches of knowledge are taught. In this sense I have used the term in these Lectures. The schools in which what is termed Secondary Instruction is given stand between the Primary Schools and the Colleges and Universities.

chemical lectures in both, he would find the same subjects lectured on, and much in the same order. Professors of Chemistry in Colleges at the present time are occupied mainly, if not entirely, like the teachers in the Secondary Schools, in imparting the acquired knowledge of the science; that is, what is already known and contained in books and other treatises on the science. By this system, or rather absence of system, the cultivation and extension of the science is greatly retarded, and as long as it continues, sound and steady progress in its applications to the Arts cannot be expected, or, at all events, will not be accomplished. It is with the object of trying to bring about a reformation of the systems in use at the present time, that this book has been chiefly undertaken.

There are three methods in use for teaching chemistry—oral instruction, books (these aided by written examinations), and practical instruction in the laboratory. We shall take these systems as those in use at the present time in the secondary schools, and we shall see in what way they are carried on, and whether they admit of improvement.

Hitherto, as is stated in the Port Royal Logic, we have employed reason for acquiring the natural sciences; but if we are to employ chemistry or any other of the Inductive Sciences as a branch of General Education, we must so teach it that it be-

must, therefore, be taught in accordance with the laws of mental evolution, and it is only by being so taught that the majority of learners will be able to acquire a sound and comprehensive knowledge of the science itself.

In every pursuit in life there is a right and a wrong method of proceeding; we have quoted unexceptional authorities to show that wrong, or at all events defective, methods have been adopted for teaching the classics, mathematics, the other Inductive Sciences, and other branches of learning; we have now to inquire whether right or wrong methods have been adopted for teaching chemistry.

Distinguished men have, at different periods, written on the Science of Method, or the Laws and Regulative Principles of Education, as Descartes, Samuel Taylor Coleridge, and others.

Descartes, after he had been educated *by teachers*, commenced then the important task of *self-education*—he says he felt like one walking alone and in the dark; he resolved, he says, to proceed so slowly and with such circumspection, that if he did not advance far, he would at least guard against falling. I did not even choose, he says, to dismiss summarily any of the opinions that had crept into my belief without having been introduced by *reason*; but first of all took sufficient time carefully to satisfy myself of the general nature of the task I was setting myself, and ascertain the TRUE

METHOD by which to arrive at the knowledge of whatever lay within the compass of my powers.

One of the rules he laid down to accomplish this most important result was the following :—

"To conduct my thoughts in such order that, by commencing with objects the simplest and easiest to know, I might ascend little by little, and, as it were, step by step, to the knowledge of the more complex; assigning in thought a certain order *even* to those objects *which in their own nature* do not stand in a relation of antecedent and sequence."*

This is a most *rational* Rule, and ought to be

* "Who is to be taken as the representative of the great epoch of the progress of science in *modern* times; that is, beginning from the sixteenth century? In different ways, Galileo, Descartes, Bacon, Newton, may seem best suited to occupy that position. But Galileo's immediate influence was limited, both as to subjects and as to the number of admirers. It was when Descartes summed up into a *system* the discoveries of Galileo and his disciples, and added to them inventions of his own, some true, many captivating, that the new physical philosophy acquired a large and vigorous hold upon Europe north of the Alps. In France especially, always eager in its admiration of intellectual greatness, Descartes was unhesitatingly regarded as the great man who brought in a new and more enlightened age of philosophy. Indeed, for a large portion of philosophy, he is still so regarded by French philosophers; and though his influence in metaphysics is to be distinguished from his authority in physics, still the ascendancy of his more abstract and general philosophical opinions was closely connected with his recognized eminence as a physical philosopher and with the admiration which his system of the universe obtained. The Cartesian philosophy was the proclaimed and acknowledged antagonist of the Aristotelian philosophy; it was the *new truth* of which the standard was raised against the *old falsehood*."—*Scien-*

adopted by every teacher of Natural Science; he ought invariably to commence the teaching of any subject, new to the learner, with some object or thing the learner knows, and on this, as a basis or antecedent, explain the easiest thing or object which the learner does not know, and so ascend little by little to the knowledge of the more complex. I have found, however, during a quarter of a century's experience as a teacher, that the majority of learners, whether young or old, expect when they commence learning any subject to be told at the first something they do not know, and look with surprise and contempt, at the first, upon a teacher who adopts this Philosophical Method of Instruction; and the more ignorant the learner is of other subjects the more he expects to be puzzled, for many think that teaching consists in puzzling or bewildering the mind. The Charlatan and Impostor always darkens knowledge with words; this is the mode he adopts for escaping detection, he tries by mere verbiage and sensational experiments to make himself, and not the subject of instruction, the object of the student's contemplation, and by this means to conceal the depth of his own ignorance.*

* Quintilian mentions a teacher of rhetoric whose constant admonition to his pupils was "Darken, darken," as the readiest mode of gaining admiration.

"It is a remark which I have generally heard highly applauded that

The two following Rules for Method are taken from the "Port-Royal Logic":—

"To treat of things, as far as possible, in their Natural Order, by commencing with the most general and simple, and explaining everything which belongs to the nature of genius before passing to its particular species."

"To divide, as far as possible, every genus into all its species, every whole into all its parts, and every difficulty into all its cases."

who estimate the depth of thought as an unskilful eye would estimate the depth of water. Muddy water is apt to be supposed to be deeper than it is, because you cannot see to the bottom: very clear water, on the contrary, will always seem less deep than it is, both from the well-known law of refraction, and also because it is so thoroughly penetrated by the sight. Men fancy that an idea must have been always obvious to every one, when they find it so plainly presented to the mind that every one can easily take it in. An explanation that is perfectly clear, satisfactory, and simple, often causes the unreflecting to forget that they had needed any explanation at all. And truths that are, in practice, frequently overlooked, they will deride as 'vapid truisms' if very *plainly* set forth, and will wonder that any one should think it worth while to notice them.

"Accordingly, if there should be two treatises on some science, one of them twice as long as the other, but containing nothing of much importance that is not to be found in the other (except some positions that are decidedly untenable), but in a style, much more diffuse, and less simple and perspicuous, with a tone of lofty pretension, and scornful arrogance, many persons will consider this latter as far the more profound and philosophical work, and the other as containing merely 'beggarly elements' fit only for the vulgar. The late Bishop Copleston describes writers who write obscurely, who foam as it were, and speak riddles, as of the '*magic-lanthorn school*,' for, he said, their writings have the startling effect of that toy."—*Extracted from* WHATELY'S *Preface to "Bacon's*

Before investigating the plan followed in writing educational works on chemistry, it will be well to recall to the reader's attention what has been stated in describing the nature and development of Perception : it is there stated (Lecture IV., page 154) that the mental act which takes place when we first look upon an object is one of *separation* and *comparison*, and this act of separation and comparison forms the first link in the whole vast chain of mental development which ensues. Every succeeding act of our mind's development is only a more progressive act of separation and comparison.

Works on General Chemistry may very correctly be divided into two classes—works of reference and educational works. The plan followed in writing works of reference on the Science is similar in principle to the one followed in constructing the dictionaries of a language; all are aware that if we want to know anything about any one of the letters of the alphabet, or about a word, say its meaning, or how it is spelled, we refer to a dictionary for the information we require. Chemistry has to do with the *elementary* and *compound* nature of *substances*, and the elements and compounds may be compared to letters and words. Letters, as all know, are the simplest or the most elementary signs employed in language; elemen-

words are formed by joining two or more letters together; and all compound substances, whether Animal, Vegetable, or Mineral, are formed by the union of two or more elements. And as there can be, and are, different words, yet composed of the same letters, as To and Too; so there are different compound substances (chemical words) composed of the same chemical letters (elements). If we want to know anything about any one of the elements, we look into a book of reference (the Chemical Dictionary) as we would into an ordinary dictionary about a letter, and we find all that was known about *that element* at the time the book was written. In like manner, if we want to know anything about a compound substance, say of what elements it is composed, or in what proportions, or what are its physical or chemical properties, we look into a work of reference as we would look into a dictionary about a word, and we find all that is known about it. No one sets to work systematically to read through a book of reference, just as no one employs the dictionary as a reading book. It must be added that the Laws and Principles of the Science are also treated of in this class of books. The largest chemical reference books in the English language are Gmelin's Chemistry and Watts' Dictionary; Gmelin's work extends to about twenty volumes, and Watts' Dictionary already extends to eight large volumes.

The majority of persons would think it a very irrational plan, and very naturally so, if languages were taught by first setting the learner to work to commit to memory the dictionary of the language to be learnt. Yet a scarcely less irrational plan is, as we shall explain, followed in the teaching of chemistry. The first work on the science which is placed in the hands of a chemical student, in nine hundred and ninety-nine cases out of one thousand, is constructed, *however small it may be*, on the same plan or pattern as works of reference—that is on the plan of a dictionary; and that plan is followed in teaching the science by means of lectures. It is altogether unsuitable, in my opinion, for commencing the work of instruction, and for the following reasons:—

1st. A plan of instruction, whether it be by books or is given orally, ought to commence with what is easiest comprehended; the lower stages of the intellect being first exercised and strengthened; and passing gradually on by a natural and proper sequence of things to what is more difficult and complex, in accordance with the laws of mental evolution. By the dictionary plan, the plan almost universally adopted, *the first lesson is as difficult* to be comprehended as *the last*, and therefore requires for its correct comprehension as advanced mental powers, and as high a state of mental discipline, as the *final one* requires;

which is contrary to the true principles of education.*

2nd. Before entering on the next objection I have to the plan described, and at present in use, I will give an extract from Dr. Morrell's preface to his English Grammar, which is founded on Becker's, principally, and other German grammars. "The chief advantage I look for," he says, "from perusing grammar on these principles is, to avoid the folly in education of putting Etymology before Syntax, and of *inculcating the mere study of individual words* and their structure, in preference to the investigation of language as the great complex organ of human thought."

As English grammar was formerly taught by commencing with the study of *individual words*, so Chemistry is taught at the present time; the study

* "The first principles of all the sciences are intimately connected with the philosophy of the human mind; and it is the province of the logician to state these in such a manner as to lay a solid foundation for the superstructures which others are to rear. It is in stating such principles, accordingly, that elementary writers are chiefly apt to fail. How unsatisfactory, for example, are the introductory chapters in most systems of natural philosophy! not in consequence of any defect of physical or of mathematical knowledge in their authors, but in consequence of a want of attention to the laws of human thought, and to the general rules of just reasoning. The same remark may be extended to the form in which the elementary principles of many of the other sciences are commonly exhibited; and, if I am not mistaken, this want of order, among the first ideas which they present to the mind, is a *more powerful obstacle to the progress of knowledge* than is generally imagined.—*The Philosophy of the Human Mind*, by the late Professor Dugald Stewart.

of the science is commenced with the study of the individual elements and compounds; and taking Hydrogen as the first element selected, its *Physical* and *Chemical* properties will be described, and frequently they are mixed up in the greatest confusion; experiments are described in books, and shown at lectures that many of the other elements will unite with it, and the method of obtaining it is also described, and frequently this is done before any of its chemical properties have been made known to the learner.

I submit this is a wrong method, whether the study of it is to be confined to students who study it for Professional or Industrial purposes, or it is employed as a branch of general *education*; for, owing to the absence of any classification of the facts, the truths are not so arranged that the Comparisons gradually increase in complexity in accordance with the Laws of Thought, or that any separation or comparison can take place; the Reason, therefore, is not cultivated, consequently the Science is not attained. "It would be a mistake," Professor Jevons states, "to suppose that the making of an experiment is inductive reasoning, and gives us without further trouble the laws of Nature. Experiments only give us the facts upon which we may afterwards reason, and it is only by careful reasoning that we can learn when the same facts will be observed

Owing to the *varying conditions* by which the combinations of hydrogen with other elements, and the decompositions of its compounds, are shown to bring about these different chemical changes, cause the experiments to be necessarily ill-arranged for instructing the mind of the learner; they are altogether unsuitable for bringing into play the *mental act* of separation and comparison, they are not consequently suggestive to the learner; they may be remembered, but they will not *fructify* in the mind, and enable the student to *conceive* from them any important chemical principles.

3rd. In the class of Educational works under review no instruction in the language of the science is given beyond a few general rules on the Nomenclature and Notation; yet the symbolic language of Chemistry requires to be taught, like all other languages, by means of a systematic plan, combined with exercises. On account of the absence of any plan for teaching the language of the science in these books, the student has often but an imperfect mastery over it after years of study. Although he could have acquired an intimate and accurate knowledge of it in a comparatively short time by a well-directed plan, so that he would not only be able to write out chemical formulæ, but also complicated chemical changes,

embody the ideas which arise in his mind from the study of the science; but when it is only imperfectly known the student will be unable, and therefore will not even attempt, to make it the instrument of thought, and it cannot be to him the nutriment of thought, and from want of it the atmosphere in which chemical thought lives is wanting. Due attention ought, therefore, to be given in any educational system of the science to the instruction of the student in the language, as a language, and not leave him to pick it up, as is the case at present, on the haphazard system. This instruction in the language of the science ought to be commenced, it will be evident to the least reflecting, at a very early period of the student's studies.*

This system is, therefore, for the reasons assigned (and others could be adduced), not in accordance with the laws of mental evolution. We will now

* I would wish the reader, before perusing this note any further, to refer back to the third Lecture (page 116), and read over again the remarks of the late Dr. Whewell and Professor Max Müller on language as the nutriment of thought. How can a chemical student think on and of the science if he has not been furnished, by being taught, with the instrument wherewith to think. What folly to attempt to teach students the science by lectures without having first taught them the language of the science: and when ignorant of the language, they cannot exercise a free and independent judgment upon the dicta of the teacher, but must receive as gospel all the errors and mistakes he commits, whether in description, or in writing out chemical equations, &c., on the

contrast a Student taught under this system with an Uneducated Workman in a Chemical Factory. Suppose, for example, the student has read in his educational book a description of, or has been told in a lecture, the plan for the manufacture of sulphuric acid. Would that so-called knowledge be *scientific* or *empirical?* Wherein does it differ from the knowledge the uneducated workman acquires in the factory? He has been taught by being directed *what to do.* Yet *we call* the *workman's knowledge empirical*, and *the student's scientific*; the difference, however, is plainly in favour of the workman, for as Chemistry is an experimental science, *it is better to be able to do a thing empirically than to read or to be told about it empirically.**

The reader who knows nothing of Chemistry will think I have drawn a very exaggerated statement of the plan almost universally followed in teaching Chemistry to *beginners;* that I have, in fact, substituted *imagination* for sober fact. I assure him I have not, and I further state that the average student, at least, who only attends lectures, is left in the condition, as regards a knowledge of the science, I have described. The living book,

* "By empirical knowledge is meant that which rests entirely on *detached* facts, without corroboration or connection with other branches of knowledge. It is contrasted to generalized and theoretical knowledge, which embrace many series of facts under a few simple and comprehensive principles, so that each series serves to throw light upon each other series of facts."

the teacher, is superior in very many respects to the printed book. In the teaching of any subject, but more especially in the teaching of the Natural Sciences, books have their value; they are always at hand to be consulted; but in the teaching of the Natural Sciences especially they must be looked upon only as adjuncts, but very important adjuncts, to the teacher, and to the student's practical study of the science himself. Although I consider the Professorial Lecture system for teaching the Natural Sciences *irrational in principle*,* yet if the teaching is to be carried on by the plan at present followed both in books and lectures, the latter have advantages over books, inasmuch as the student witnesses the experiments in the one, and only reads about them in the other. The same difference exists as between seeing a picture and simply reading about it.†

Adopting lectures as the mode for teaching an experimental science like Chemistry, is as irrational as it would be to teach *drawing* or *painting*, by lecturing to the student on the subject, instead of teaching him to draw or paint himself; or to

* By Professorial Lectures I mean that class of lectures where the subject matter of the lecture is simply placed before the learner, no attempt being made to ascertain whether as a class or as individuals the hearers understand *what is being said.*

† "Lectures. These, whether public or private, are surely the

lecture to those who want to learn how to sing or play upon an instrument, instead of teaching them to sing and play themselves.

But if the student were to perform the experiments himself, the class of experiments shown at lectures are unsuitable for a first course of instruction. For the experiments are brought about, as we have already stated, under such varying conditions, that he fails to note the conditions, and only sees *the bare fact* that such an experiment takes place; consequently he does not learn when the same facts will be observed again. Experiments, as Professor Jevons states, only gives us the facts upon which we may afterwards reason, and it is only by careful reasoning that we can tell when the same facts will be observed again.

"The Philosophy of Science, it must never be overlooked, consists of two principal parts—the methods of investigation and the requisites of proof. The one points out the roads by which the human intellect arrives at conclusions, the other the mode of testing their evidence. The scientific intellect, both in the individual and in the race, must learn in the more elementary studies that art of investigation and those canons of proof which are to be put in practice in the more elevated. No intellect is properly qualified for the higher part of the scale, without due practice in the lower" (John

Few, if any, will deny the truth of the above statement by Mr. Mill; and they must, I think, further admit that neither by lectures as a mode of conveying instruction, nor the mode of treating the subject which is followed in lectures and in educational books, are the methods of investigation and the requisites of proof taught in the more elementary studies of Chemistry; and I shall in the next Lecture show that they are not taught when the student reaches Chemical Analysis, as that branch of the science is generally taught.

It can scarcely be doubted that if teaching had to be commenced at the present day, when books on every subject are plentiful and comparatively cheap; and if the Inductive Sciences, or any one of them, were placed upon the same level as classics and mathematics as Educational Instruments, teaching by lectures would not be the plan followed for teaching these sciences, even in Colleges and Universities, whatever it might be with regard to the teaching of classics and mathematics. Lectures originated before the invention of printing; they were employed as substitutes for books; for before the invention of printing "the great majority of students" had no other means of becoming acquainted with the subjects of their study but by hearing the teacher read the manuscripts. But, having become once established

this mode of teaching has continued, although the reason for its establishment has long since ceased. One reason may be, that it is a very easy system; five hundred students can be taught by this means as easily as one; the difficulties each individual mind has to contend with in the different studies does not entail upon the lecturer any labour, for he cannot become aware of them in lecturing. Hence Grinders have arisen as supplementary to the Professors in Colleges and Universities where the Professorial system is followed.*

In lectures the learner is the more *passive* and the teacher the more *active* of the two agents—

* "The first considerable change which the system of instruction in the University underwent was consequent upon the great multiplication of books which the invention of printing introduced. Before this important epoch in the history of the progress of knowledge, the great majority of students had no other means of becoming acquainted with the subjects of their study but by hearing the manuscripts read (with or without the glosses or comments which generally accompanied them) in the public schools, duty which furnished a daily and principal employment to the bachelors of arts and regent masters of the University. The method of reading was usually sufficiently slow and deliberate to enable the students to copy the actual words, or at all events the import of what was read, which formed the only manuscripts to which they commonly had access; for the complete manuscripts of the classical or other authors were articles much too costly for a poor student to purchase, and the libraries were in general very scantily stored, and were only accessible under restrictions and conditions which confined them almost exclusively to the regents only."—*Observations on the Statistics of the University of Cambridge*

teacher and learner—in the work of instruction; if, consequently, sound knowledge could be obtained in this manner there would be a *Royal Road* to learning, which is impossible; "for, that exertion is necessary—that after all possible facilities have been afforded, it is still a matter of toil and struggle to appropriate to ourselves the acquisitions of great discoveries—is not to be denied. Elementary mechanics, like elementary geometry, is a study accessible to all; but, like that too, or perhaps more than that, it is a study which requires effort and contention of mind—a forced steadiness of thought. It is long since one complained of this labour in geometry, and was answered that in that region there is no *Royal Road.* The same is true of Mechanics, and must be true of all branches of solid education. But we should express the truth more appropriately in our days by saying that there is no *Popular Road* to these sciences. In the mind, as in the body, strenuous exercise alone can give strength and activity. The *art of exact thought* can be acquired only by the *labour of close thinking*" (Whewell).

But I must not be misunderstood with regard to the system of teaching by lectures. I do not mean to state that no subjects, and under no circumstances, can this mode of teaching be used effectively, for the form of this book itself would be a contradic-

tion of such a statement. I believe there are subjects that can be taught by this method; and when the student of any of the Inductive Sciences has acquired *a mastery* over the acquired portions of that science, I believe the *newly discovered portions* of the science might be very effectively placed before him in the form of lectures. But what I maintain is, that the lecture system is the least efficacious, or, I would say, the most irrational and worst system for *teaching* the Inductive Sciences.

Bacon states in his great work "Novum Organon," "There are two ways, and can only be two, of seeking and finding truth. The one, from sense and particulars, takes a flight to the most general axioms, and from those principles and their truth, settled once for all, invents and judges of intermediate axioms. The other method collects axioms from sense and particulars ascending *continuously and by degrees*, so that in the end it arrives at the most general axioms; this latter way is the true one, but hitherto untried." Bacon, it will be seen, insists upon a *graduated and successive induction*; and Whewell, in commenting upon it, observes, "It contains a view of the nature of true science most exact and profound; and, so far as I am aware, at the time perfectly new. . . . . The truly remarkable circumstance is to find this

observation by limited steps, through successive gradations of generality, given at a time when speculative men in general had only just begun to perceive that they must begin their course from experience in some way or other. How exactly this description represents the general structure of the soundest and most comprehensive physical theories, all persons who have studied the progress of science up to modern times can bear testimony."

The facts, illustrated by experiments at lectures, and given in educational works, and which are employed to teach beginners in the study of Chemistry, *are not graduated*—the first lesson, I have already stated, is as difficult to be comprehended as the last: they are, in the way they are arranged, disconnected for beginners, consequently they remain in the student's memory in a confused and unorganized state; and truth, it is well known, emerges more easily from *error* than from *confusion*. Bacon judged rightly concerning the mode in which facts are to be employed in the construction of science; but facts are but one of two ingredients in knowledge, and both are equally necessary: *ideas*, the other ingredient, are as indispensable as facts; and Bacon neglected this great portion of his subject, and he contributed, as Professor Jevons states, "to spread abroad the

begin by accumulating facts. His notion of scientific method was that of a *kind of scientific book-keeping*. Facts were to be indiscriminately gathered from every source, and posted in a kind of ledger, from which would emerge in time a clear balance of truth. It is difficult to imagine a less likely way of arriving at great discoveries."*

If it had not been that the plan followed in teaching Chemistry by lectures and in books was the plan that was first originated, and is still continued, for registering the facts of that science in books—the plan being, as we have stated, the plan on which a dictionary is constructed—it would have been supposed that the authors of the plan as an educational one were so ignorant of the mode the mind receives, appropriates, and creates

* The greater the array of facts, the less is the probability that they will by any routine system of classification or research disclose the laws of Nature they embody. Exhaustive classification in all possible orders is out of the question, because the possible orders are practically infinite in number. It is before the glance of the philosophic mind that facts must display their meaning, and fall into logical order.

"Hundreds of investigators may be constantly engaged in experimental inquiry, they may compile numberless notebooks full of scientific facts, and may frame endless tables full of numerical results; but, if the views of the nature of induction here maintained be true, they can never by such work alone rise to new and great discoveries. By an organized system of research they may work out deductively the detailed results of a previous dis-

knowledge, that they had in ignorance rejected what was true, exact, and profound in the plan proposed by Bacon, and had adopted, through ignorance, what was false and hurtful in the scheme he proposed. All that can be stated in favour of the plan is that it brings before the student's attention a variety of facts; and if facts were the only ingredients of knowledge, this might be the proper method, but as they are not the only ingredients, it is not the proper, but the wrong, method: science is not taught by simply filling the memory of the learner with any number of facts. "The one great method of inductive investigation consists in the union of hypothesis and experiment, deductive reasoning being the link by which the experimental results are made to confirm or confute the hypothesis." And in teaching the acquired portion of the science to beginners this one great method of inductive investigation ought to be followed as closely as possible, so that in the more elementary studies the student would learn that art of investigation and those canons of proof which are required to be put in practice in the more elevated.

Before contrasting the system in use with the one I propose, it will be desirable to recall to the reader's recollection what has been stated in the previous lecture in regard to the difficulty the

mind experiences in developing into that higher stage of thinking which is termed the logical processes, where knowledge begins to be organized. It was shown that inferior races, as the Sandwich Islanders, the Australians, Negroes, &c., are quick in all the earlier parts of their education, appearing to be quicker than the children of superior races, but their minds cannot respond to relations of even moderate complexity, they are unable to understand reasonings which exceed a certain degree of abstruseness; and this difference exists among individuals of the higher races; the principal and most characteristic difference, it has been stated, between one human intellect and another is their ability to judge correctly of evidence; and Mr. John Stuart Mill states that the intellectual part of our education has nothing more important to do than to correct or mitigate this almost universal infirmity—this summary and substance of nearly all purely intellectual weakness.

I have said that the study of the science is commenced with the study of the individual elements. In order to illustrate in a general way the plan, we will employ letters to represent the elements; and taking the letter A to represent one, its physical and chemical properties would be described, and they are very frequently jumbled

ments would be shown or described that this element could combine or unite with some of the other elements, say C, D, E, and by these unions the compounds A C, A D, A E, would be formed or produced. It would also be shown how the element under consideration could be obtained in its free or uncombined state from some of its compounds; how A, for instance, could be obtained from the compounds A C, A D, A E; and this extraction—preparation it is generally called*—is frequently shown or described before the learner has been made acquainted with any of its physical and chemical properties—which, to say the very least, is illogical in the extreme; and to render it still more confusing to the beginner, these unions (combinations) and disunions (decompositions) of A and the other elements are brought about, not under the same, but under varying conditions, different agents, as heat, light, electricity, &c., having to be employed, and likewise different reagents (substances employed to effect a chemical change on other substances) are frequently required to effect the chemical changes

* The obtaining an element from its compounds is frequently called in ordinary language *extraction;* and I think it is very properly called extraction. We speak, for instance, of the extraction of this or that metal from its ores; the chemical operation employed for the extraction being called "smelting," because heat was formerly always employed for the extraction, the ore being melted or

desired. And no word of explanation of the language of the science has most probably been given.

I will give an extract from the first lesson in a small book on Chemistry, which, from its price, two shillings, would show, if it were not stated in the book itself, that it was intended for beginners. The book is thus commenced :—

"*Lessons in Elementary Chemistry.*

"LESSON I.—HYDROGEN.

"EXPERIMENT 1.—Fill a glass cylinder (or large test-tube) with water, cover it with a watch-glass or small plate, and invert it over a basin of water, taking care not to allow any air-bubbles to get into the cylinder. Remove the cover under water ; the water in the cylinder will remain supported by the pressure of the atmosphere. Next procure a piece of sodium of the size of a small pea, wrap it up tightly in a small piece of fine soft wire-gauze, and hold it by means of a wire fastened to the wire cage, or by the aid of a small spoon, as seen in Fig. 1 [a figure is inserted illustrating the apparatus], underneath the mouth of the inverted cylinder. Sodium being a soft wax-like metallic body, which has a great affinity for oxygen—a constituent of the atmosphere—ignites spontaneously in air, and has therefore to be kept in petroleum, a liquid body which contains no oxy-

pieces, the cutting should be effected under petroleum, and the required piece removed on the point of a penknife to dry blotting-paper, and rapidly freed from the adhering petroleum by gentle pressure between folds of the paper. To avoid accidents from burning it should on no account be touched with the fingers. Gas-bubbles are speedily observed making their way upward through the water, and being lighter they displace the water. The bubbling (evolution) lasts a few seconds, and the sodium is seen to disappear entirely. By repeating this operation, if necessary, the whole of the water in the cylinder can be displaced, and a sufficient quantity of the gas collected for examination.

"Now, what do we learn from this experiment? From the fact that the cylinder can be turned upside down, without the water running out, we learn (1) that the water is held up by the pressure of the atmosphere, in accordance with Torricelli's law—viz., that a column of water, thirty-three feet in height, confined in a tube, closed at one end, would, in like manner, be held suspended over water. (2) That a gaseous body (hydrogen) may result from the chemical action of a solid (sodium) upon a liquid body (water), and that the chemical change is induced by the affinity which the metallic body sodium has for oxygen, no matter whether present in air or as a constituent of water.

We have yet to examine the products of the change—viz., the gaseous body and the new compound which the metal sodium formed with the remnant of the water. Since the gas can be left confined over water without perceptibly decreasing its bulk (100 volumes of water are known to absorb only 1·9 volumes of hydrogen), we learn from the experiment (3) that we have to deal with a gas which can be collected over water without material loss. We also perceive (4) that the gas is colourless. On closing the cylinder with the glass plate (best greased) under water, removing from the water and placing it again in an upright position, we may keep the gas unchanged if the glass plate fits tightly. On bringing a lighted taper near the gas, a test invariably applied to gaseous bodies, we learn (5) that the gas is inflammable; it burns where it is in contact with air with a feebly bluish wave—like flame, but gives out a very faint light only. The hydrogen forms water with the atmospheric oxygen, hence its name hydrogen, or generator of water (from the Greek words ὕδωρ, water; γεννάω, I generate).

"We have now, lastly, to examine the water which is left in the basin. Chemists possess, in test papers prepared from certain soluble vegetable colouring matters, such as litmus, turmeric, &c., a capital and simple means of testing liquid bodies. When the litmus is turned red the liquid is termed

acid. The blue colour of a solution of litmus can be formed red by the addition of a single drop of a very dilute acid; and by dipping unsized filter-paper into this red fluid, we obtain, on drying, a red litmus-paper. If this be put into a liquid containing substances such as soda or lime, the acid absorbed by the paper is neutralized or rendered inactive, and the original blue colour is restored. Bodies which produce such an effect are termed alkaline bodies. Papers prepared with a solution of turmeric—a yellow colouring matter—are turned brown by an alkaline body, and green by an acid body. The water used in the experiment should be tested first, both with red and blue litmus-papers. On slipping litmus-papers into the water the papers should remain unchanged (neutral) *before*, but will show a strong alkaline reaction *after* the experiment. The water left in the basin imparts also a soft soapy touch to the skin; and on evaporating a little in a glass or porcelain dish it leaves a fixed residue of caustic soda or sodium hydrate, possessing these properties in an increased degree.

"Chemists have agreed to use symbols in place of words (generally the first letter of the word, mostly of Latin or Greek origin), and to express chemical changes by symbolic equations; the change whereby hydrogen is produced is thus expressed as follows:

$2OH_2$	+	Na_2	=	H_2	+	$2NaOH$
Water		Sodium or Natrium		Hydrogen		Sodium hydrate or Caustic Soda.

which reads thus :—Water to which metallic sodium has been added yields hydrogen gas, and leaves a weak solution of sodium hydrate or caustic soda. Other metals, such as potassium, calcium, &c., decompose water likewise at the ordinary temperature, combining with the oxygen, and setting free the hydrogen ; others, again, only when heated, or when steam is passed over the heated metal, such as iron, &c., confined in a porcelain tube and heated in a furnace. Other metals, lastly, possess little or no chemical attraction for oxygen, and do not therefore liberate hydrogen under any circumstances—*e.g.*, platinum, gold, &c."

The preceding extract occupies in the book from which it has been taken three pages, and the lesson occupies ten pages in all ; the method of preparing hydrogen by the action of hydrochloric acid or sulphuric acid on zinc is next described after the extract given. This work I have selected as an illustration of the kind of book which is employed to teach beginners, not because it is much different to other books of the same kind, but because it is stated in the preface that it has been prepared in order to ease the teacher's task of conveying, in twenty lessons, sound chemical instruction to their

pupils, and to help the latter to get as quickly as possible over the difficulties which the study of Chemistry presents. It is based, it says, upon the plan sketched out in the *Science and Art Directory*, which there is really little, it says, to find fault with, except, perhaps, on the ground that it expects too much from young pupils, such as are usually found attending the elementary stage of instruction. It further states that the author has confined himself all but exclusively to the simple experiments traced out by Dr. Frankland.*

I now wish the reader to examine with me this extract and see whether Chemistry so taught will prove an instrument for perfecting the reason, which is or ought to be the object of all studies that are employed in general education. The mental images, ideas, that will be formed from these experimental facts cannot blend, for the facts are unconnected, no two of them being similar, and the ideas cannot become associated except by an unnatural system, because there is no logical affinity between them ; and there can be no objectifying of any ideas the learner may form, for he is

* In most of these books, I might say in all, even the smallest, applications of the science are described, as the manufacture of sulphuric acid, chloride of lime, &c., which I think is about as rational as it would be to commence teaching book-keeping when the pupil was being taught addition, subtraction, or division.

ignorant of the instrument, the language, for objectifying them; and for the mind to develop we must be able to objectify our ideas. Humboldt says without perpetual transference of subject to object and object to subject, which is accomplished only by language, no concept can be formed, and, consequently, *no thinking* is possible. And the ideas, not being associated, must fade away from the memory in no long time, if even ideas derived from other unconnected facts described in subsequent lessons *did not drive them out.* And if separation and comparison come into play at all, it must be of the most rudimentary kind, and must continue to remain so; it can never emerge into judgment or reason, still less into science.*

* It is a common belief that what is seen is seen completely, that is correctly, which is about as correct as to affirm that what is read is understood. All human beings observe, yet it is a *rare talent* to observe correctly; some do not observe *one-half* of what passes before their eyes; others believe they see a great deal more than actually occurs: others again see the whole, but not being able, from want of that particular education, to make a correct mental analysis of what they see, which is necessary for correct observation, they see it confusedly by joining what ought to be separated, and separating what ought to be united; and they are not able to perceive what are the unimportant, and what are the important, parts for the particular purpose in view, but they take *a note* of all the circumstances, assigning to the unimportant a value equal to the important ones. This mistake is generally made by those who witness experiments at lectures; and it is fostered by those *mechanical* teachers who require their hearers to take down all that is exhibited and said. Latham calls this mechanical mode of taking notes, *dictation*, and he says such dictation is not *teaching* at all, and is superseded by the multiplication of books.

It is not surprising that many Educationists who .have received a University education have objected to the introduction of the Inductive Sciences, especially Chemistry, as subjects of instruction, into Secondary Schools ; for defective as the methods have been for teaching Classics and Mathematics, still as the pupils have themselves to work at these subjects under the direction and aid of the teacher, they do make some visible progress ; and owing to the effort and contention of the mind, which more or less takes place, the mind becomes strengthened ; but in the teaching of Chemistry by the system followed all that the pupils have to do is to *watch* and *listen to* the teacher ; and when the novelty of seeing chemical experiments has passed away, chemical lectures, from their not being understood, are attended with indifference, *especially* if at the school the other branches of study *are efficiently taught :* as a boy said to me, *We do not understand it, and therefore we do not like it.* It is useless to put before boys, for it will have no effect upon at least ninety-nine out of every hundred, as an inducement to urge them on in the study of a subject, that it will be useful to them in after-life—this has no effect upon them, the object is far too remote to have any influence ; but if a subject is so taught that they can understand it, they will enjoy it and be eager to learn, especially if it be one of the Inductive

Sciences. If in schools a subject is taught in such a way that, beyond a few stray and disconnected facts, it is incomprehensible to the learners, the time occupied in teaching it is not only wasted, but the superficial teaching in that subject is an hindrance to the acquiring of sound knowledge in all the other subjects ; but the ill effects I believe extend still further ; I believe that superficial teaching in schools imperils the success in after-life of those who have been so taught, where mental power is required.

The mistake—the majority of those who have written educational works on Chemistry, I believe to be, that they have looked upon the *matter* as the sole object of the book, and neglected altogether the *mode* of communicating it ; if this view of the construction of these books be correct, and I think it must be admitted it is, they cannot fulfil the true end of all higher education, "which is not so much to fill the mind, as to quicken and train its powers —not so much to impart knowledge, as to awaken thought."

As if to increase the difficulties, there has of late years been a great tendency to employ at experimental lectures complicated apparatus, where simpler apparatus would equally answer the purpose ; this adds to the difficulties young students experience in following the experiments and

complications of the apparatus add to their bewilderment, and have a tendency to draw off their attention from the experiment itself to the machinery employed, which after all is only a means to an end. And further, unnecessary expense ought to be avoided in teaching science, as in every other pursuit; and the teacher who is favourably situated as regards funds for the procuring of apparatus, ought to remember that it may be placing obstacles in the way of those he is teaching in prosecuting or teaching science themselves, if he indulges in costly instruments when less costly ones would be as effective. Teachers who are supposed to be instructing those who are to be science teachers in more primary schools should certainly make use of the least complicated and costly apparatus that it is possible to employ, in order to show them how to teach science in the way most suitable to the circumstances in which they will be placed, both as regards the time capable of being devoted to the fitting up of the apparatus, and to the amount *they* will have to expend upon it; independent of the fact that it is better calculated, as educational machinery, to aid the teacher in the work of instruction.

That Prince of Experimenters, the late Professor Faraday, always employed apparatus of the most simple character; and Professor Tyndall in

giving a course of lectures on Electricity, &c., a few years ago, employed very simple and inexpensive apparatus, in order to show, as he stated, his hearers that all the experiments he brought before them could be simply and inexpensively performed. And I have shown by a quotation I have given in Lecture I., page 15, from the late Professor Clerk Maxwell's work on the "Theory of Heat," the opinion that distinguished Physicist held as to what could be accomplished with simple apparatus.

It is only necessary occasionally to employ even complicated apparatus in conducting original investigations; Lavoisier expressly remarks, "In performing experiments, it is a necessary principle which ought never to be deviated from, that they be simplified as much as possible, and that every circumstance capable of rendering their results complicated be carefully removed." Many of Newton's experiments were carried out with the simplest apparatus. And in referring to his experiments with the pendulum, Professor Jevons remarks, "In Newton's decisive experiments similar conditions were provided for, with the *usual simplicity* which characterizes the highest art." I have seen it somewhere stated that Wollaston conducted all his investigations with apparatus which a tea-tray would hold, and worth about five shillings; and the apparatus Cavendish

equally inexpensive. The substitution of complicated for simple apparatus and processes has another bad effect on the learner—it is training him to do the same, and he may by adopting the plan miss the truth in any experimental inquiries he may afterwards undertake; Newton, for example, failed to discover *the dark lines* by not obtaining *the Solar Spectrum* under the simplest conditions.

It now remains for me, in connection with this part of the subject, to describe a method more in harmony, I conceive, with the laws of thought; and I hope as I unfold the plan I shall convince my readers of this; and if the plan I propose should be more perfect than the one at present adopted, it would render the science a more valuable instrument for training the mind than the plan at present in use; and if the reason is not cultivated, the science is not attained, for unless the first is reached the second is not gained; for we cannot observe or experiment in a scientific manner, or reflect without the aid of reason. And here it may be as well to observe that the mature and cultivated mind has to pass, although it may do so with facility, through the lower intellectual processes before it can exercise the highest on any new branch of study.

All chemical experiments are either experiments of combination or experiments of decom-

Now, instead of showing, as is done by the plan at present in use, under each separate element,* that that particular element under consideration at the time will combine (unite) with certain of the other elements, and how each individual element is extracted from some of its compounds, thus mixing up experiments of combination and experiments of decomposition, and experiments in which both combination and decomposition take place in, for the beginner, inextricable confusion—we commence thus: The different states in which matter can exist is shown, and the learner commits to memory the names and symbols of the more commonly occurring elements, just as a person before attempting to read learns the names of the letters of the alphabet. In addition to learning the names and symbols, he also learns in what state—fluid, solid, or gaseous—these elements exist when *free* or *uncombined* under ordinary conditions. The learner, having arrived thus far, *is shown by experiments*, not that each individual element separately can combine with some three, four, or more other elements, but that two elements can combine (unite) together, not limiting it to any two particular elements. The student cannot fail to observe in witnessing these experiments, even if

* In these explanations I shall take the old view of the constitution of the elements, as I can the more easily make my views known to the non-scientific reader.

his attention were not, as it ought to be, directed to it by the teacher, that the combination of the elements is frequently attended with an evolution of light, and generally with a development of heat, and that it is often attended with a change of colour, and that the properties of the individual elements are extinguished (become latent) *during the time* the elements remain united, the compounds formed by their union possessing *properties altogether different* from those of the elements of which they are composed or formed.

I think it will be admitted that there is nothing bewildering or incomprehensible in this, but that it is capable of being, as I know, from my experience as a teacher, it can be thoroughly, understood by very young minds.

Having shown that the elements can unite together and that their union is attended with certain manifestations (phenomena), as the disappearance of the properties of the elements in the compounds, the evolution of light, &c., the conditions necessary to bring about the union of the elements is then experimentally shown. It is shown that a certain temperature is requisite for the combination of substances, and that the temperature required varies with different elements—phosphorus and chlorine combine, for instance, at the ordinary temperature of the atmosphere, whilst phosphorus and some of the other elements require for their

combination a temperature higher than the ordinary atmospheric temperature. It is then shown experimentally that the combination of some of the elements can be brought about by electricity and that the union of others is effected by the influence of light. It is subsequently *shown by experiments*, that just as there are different words composed of the same letters, as To, Too, so one element can frequently combine with another element in more proportions than one, different compounds *composed* of the same elements being thereby produced. The student's attention being at the same time directed to the phenomena which attend these chemical changes, and also to the conditions under which they are brought about.

It is then shown experimentally that compound substances, like the elements, can unite together, forming, of course, more complex compounds, the *phenomena* and *conditions* attending, and required for, these combinations being observed, as in the previous examples.*

During the progress of these lessons the learner

* These lessons are to be given by the teacher on the tutorial system: that is, the teacher not only puts before the pupil what it is desired he should know, but by catechetical examinations during the *delivery* of the lesson he ascertains the difficulties each pupil experiences, and by explanations suited to the mental capabilities of each he enables them to understand what it was *intended* they should *know*. For a catechetical lesson or lecture, the class must be limited; whilst any number can attend a Professorial

has, at stated periods, to write out answers to questions which are given him; he thus becomes trained at the same time in the objectifying of his ideas.*

It is then shown that substances, when they chemically combine, unite always in certain definite proportions by weight, and the learner has to work out a series of examples illustrating this important principle.

A systematic course of study on the nomenclature and notation of the science, including the expression of chemical changes, by means of diagrams and equations, is next taught by means of appropriate courses of exercises in the various divisions of the subject, which the learner has to answer.

The conditions which favour the decomposition of chemical compounds is then studied. As the majority of learners will be unacquainted with chemical manipulation, the experiments on combination are to be performed by the teacher, to the entire class, he giving all necessary instruction with each experiment. The experiments on decomposition ought, whenever possible, to be performed by each individual learner, the teacher superintending and instructing each of them separately.

The influence which heat, light, electricity, cohe-

* The examination questions are to be so framed that only the portion of the language of chemistry which the student has become acquainted with, is required for correctly answering them.

sion, elasticity, &c., exercise in promoting chemical decompositions the student becomes acquainted with by performing a course of experiments illustrative of the influence which each of these agents exercise, and always expressing in his note-book the chemical changes which occur in each experiment in an equational form. Written examinations also form part of this division of the course; in order to continue the training of the student in the objectifying of his ideas.

The Arithmetical problems, as they have been called since I first introduced them, next follow, and this is the only part of the plan I have described, and which I published a good many years ago under the title of the "First Step in Chemistry," which has been thoroughly followed by other teachers (*see* Appendix III.); in all other respects they follow the old and, as I consider, in the present state of chemical science, *irrational* plan.* Before pointing out some of the

* I am, perhaps, not quite exact in stating that no part of the plan I introduced has been followed but the arithmetical problems, as the larger number of the *educational* works on general chemistry, which have been published since I published my "First Step in Chemistry," have followed the plan I introduced into that book of giving a series of questions at the end of each distinct section. Since I introduced the plan into my qualitative analysis it has also been followed in some books on that branch of the science. But when the language of the science has not been taught, the answers to the examination questions, whether the subject has been heard at lectures or read in books, can only be parrot-like, a

advantages of my plan, I will give one of these arithmetical problems, as it may interest those who are not acquainted with them.

A Chemical Manufacturer delivers to his workman 50 lbs. of metallic silver to be converted into nitrate (caustic). What amount by weight ought the workman to deliver to him of the caustic?

The Archbishop of York. in that portion of his work, "An Outline of the Laws of Thought," devoted to Applied Logic, defines SCIENCE to be a system of principles and deductions to explain some object-matter. And, he states, "to fulfil its intention every science must have attained to true statements concerning its object-matter, so far as the nature of the case and the present means of examination allow; it must be able to define the object-matter, and its several subordinate parts, with clearness and precision; and it must be able to indicate the extent of the domain the object-matter covers; and, lastly, it must exhibit these results in a systematic and harmonious shape. For the first it must employ *Induction* and *Deduction*; the second is the province of *Definition*; the third is provided for by *Division*; and the fourth may be referred to *Method.*"

Science consists of two chief parts, *Construction* and *Arrangement.* Science is grouped in his work under these two divisions, and the subdivisions of

A. CONSTRUCTION OF SCIENCE.

Induction and Deduction.

B. ARRANGEMENT OF A SCIENCE.

Method. Definition and Division.

Of Method he speaks thus :—" As method in the highest sense is a natural gift rather than a technical system, it can be best understood by studying a few examples, which have proceeded from minds of the highest order. It will be found that whilst the deductive and the inductive orders have been followed, with the aid of definition and division, none of these means has been exclusively employed; and the due admixture of them, and the degree of preponderance to be assigned to any one, have been regulated by the imagination and taste of the constructor." He notices the kind of order which prevails in "Euclid's Elements," and he says, "In 'Plato's Republic,' one of the noblest examples of method, successive definitions of justice are brought to the test and rejected; and then division preponderates, in the enumeration of the powers of the human soul, and of the classes in a state that answers to them; as well as of the declinations through which the perfect polity, if it could be constructed, would have to pass. The whole is fused together and adorned by a dramatic element, in such a manner as to render this dialogue the finest work of pagan philosophy."

We have considered whether the system at present followed in teaching the elements of Chemistry accords with the laws which govern the development of the intellectual faculties; but there is another view of it which we will consider along with the plan I propose in place of it. Not so very long ago all that was known of the twin-sciences, Physics and Chemistry, occupied in description only as many pages as the new theoretical and practical discoveries now made known each year occupy in Chemistry alone. In the infancy of Chemistry, when it consisted of little more than a collection of facts, the plan at present followed for teaching the elementary portion of the science, was perhaps the only one possible. But with the present extension of the science, a philosophical method of teaching the beginner is required, and is capable of being constructed.* We now know that each individual element is capable of entering into union with all the other elements, for although it has not in every instance been accomplished, there can be little or no doubt that if the elements that prove the exceptions at present were brought together under the proper conditions, they would

* I believe, as I have previously stated, that the present construction of the elementary-books on the metalloids and metals for students is far from philosophical, and that a plan more systematic, and therefore more philosophical, could be invented; and students, of course, require a book on these subjects after they have advanced a certain way in the method I have pointed out.

unite. We further know that all chemical compounds are capable of being decomposed. Now, if the combinations of the different elements with each other all took place under exactly the same conditions, and if the decomposition of all compound substances were brought about in exactly the same way, we should be able to predict, before trying the experiment, how the combination of this or that element with another would take place, and how the decomposition of every compound could be effected; but this is not the case; the conditions vary with the combinations and decompositions of the different substances. Hence the reasonings in Chemistry, and, indeed, on all matters of fact, are so much more complex than is required in Mathematics; in the latter science *reasoning* alone is required, there is needed no exercise of the judgment respecting probabilities; hence the longest mathematical demonstration is so much more easily constructed and understood, than a much shorter train of just reasoning concerning real facts. The former, Archbishop Whately says, "has been aptly compared to a long and steep—but even and regular—flight of steps, which tries the breath, and the strength, and the perseverance only; while the latter resembles a short—but rugged and uneven—ascent up a precipice, which requires a quick eye, agile limbs, and a firm step; and in which we have to tread now on

this side, now on that—ever considering, as we proceed, whether this or that projection will afford room for our foot, or whether some loose stone may not slide from under us."

Which of the two plans is the more philosophical, and therefore the most valuable for mental discipline, as well as forming the best foundation for the cultivation of the science? The one that teaches, or attempts to teach, the science to beginners by bringing before them a number of disconnected facts, which must remain, however long they may be remembered, as unorganized knowledge, unless the teaching is supplemented by a much more extended and different course of study.* Or the plan which makes the learner know once for all that the different elements can unite to-

* "Any one would be far indeed from being a follower of Bacon who should despise logical accuracy, and trust to what is often called *experience*; meaning, by that, an extensive, but crude and undigested observation. For, as books, though indispensably necessary for a student, are of no use to one who has not learned to read, though he distinctly sees black marks on white paper, so is all experience and acquaintance with facts, unprofitable to one whose mind has not been trained to read rightly the volume of Nature, and of human transactions, spread before him.

"When complaints are made—often not altogether without reason—of the prevailing ignorance of facts, on such or such subjects, it will often be found that the parties censured, though possessing less knowledge than is desirable, yet more than they know what to do with. Their deficiency in arranging and applying their knowledge, in combining facts, and correctly deducing, and rightly employing, general principles, will be, perhaps, greater than their ignorance of facts."—Archbishop Whately.

gether, and that all compounds can be decomposed; and making the student practically acquainted with the conditions, as far as they are known, by which combinations and decompositions can be effected. By the first plan the science is taught as it would be if it were in its infancy; it is taught as if we were for the first time learning that hydrogen and each of the other elements can unite with others, and that each element can be extracted or eliminated from some of its compounds. By this method, if it were carried out in its entirety, which is absolutely impossible, the science as it becomes more perfect would become more difficult to learn, and the manuals for teaching it would become, almost yearly, more voluminous; the plan cannot be carried out in its entirety; it would be impossible to bring before the learner all the facts of Chemistry; and the imperfection of the plan is illustrated by the books for the teaching of the science. There are fewer, leaving out the works of reference on the science, larger manuals now in the English language than there were thirty years ago; and the smaller manuals which have been published in that time keep decreasing in size, although new chemical facts are discovered at such a rapid rate.

The facts are only barely stated in these books, all that is necessary for making them illustrative of some of the principles of the science is left undescribed. They are, therefore, equally unsuit-

able for the professional, as well as for the general, student. The description which Archbishop Thomson gives of a class of books on Logic, may be as correctly employed, with a few verbal alterations, to these manuals of Chemistry. What is the course adopted? We attenuate the science, where we ought to simplify it; we reduce the size of our manuals, in the vain hope of lessening their difficulty; and there remains little more than a catalogue of unconnected facts alluded to in language which is virtually unknown to the learner; all that would give life and zest is left out, and the dry bones are all that is offered to the learner. No wonder that untrained minds are repelled from learning the science when such indigestible matter is placed before them.

When chemical investigations are undertaken with the object of producing some new compound, or of forming, or decomposing, one in a manner not hitherto known; the difficulties of the investigation consist in a great measure, in discovering the conditions by which the chemical changes in question can be brought about. This important part in chemical investigations has been too much neglected by chemists; their chief desire has been, and still is, to produce or decompose this or that substance; they seldom attempt to discover all or even sometimes any of the conditions necessary for the success of the experiment, and the exclusion

of conditions which are unnecessary. "Some of Faraday's most elegant and successful researches were devoted to the exclusion of conditions which previous experimenters had thought essential for the production of electrical phenomena." The substance of which the poles of a battery were made was considered, until he proved the contrary, of great importance.

This inattention to the conditions by which changes are brought about renders the science *more empirical* than it otherwise would be, and entails difficulties both in the prosecution and extension of the science itself, and its applications, which ought not to exist. When one attempts, especially in organic Chemistry, to make some of the less simple and less known substances from the descriptions given even in works of reference, one finds that, beyond knowing that such a substance was made from such materials, and by such re-agents, one has, so far as the conditions involved in its production are concerned, to rediscover it for oneself. But the difficulties are vastly increased when there has to be carried out an experiment on the manufacturing scale which has previously only been conducted on the laboratory scale. It is in the manufactory especially that the one who has studied and paid great attention to the conditions by which chemical changes are brought about will prove so superior as a chemical

manager to one who has only been taught bare facts. For, however thoroughly the experiment may have been investigated in the laboratory, interference will almost be certain to arise on the large scale from conditions hitherto unsuspected; and also conditions that were in the laboratory considered essential will be found, as Faraday discovered about the poles of the battery, unessential, and others may have to be excluded. But even if the experiment has been tried on the large scale, but *time* has not come in as an element in the working, the experiment not having been carried on continuously or only for a short period; it will almost invariably be found that conditions have been overlooked, others which have been considered essential will be found unimportant, on this large scale, that appear, and interfere with the success of the process when time has to be taken into account, the process having to be worked continuously. The chemist who simply knows chemical facts is of very little use, nay often proves a very great obstructive in a chemical factory, when difficulties like these have to be encountered. It is owing to conditions arising adverse to the process as a manufacturing one, and which are not overcome or avoided, that cause so many inventions that are perfect in theory, and that have been worked out with success in the laboratory, or even on a larger scale,

to fail in practice. I intended some time ago to write a paper on the importance of bringing preminently forward in books and in teaching the science, the conditions necessary for effecting chemical changes; the title of the paper would have been "Some of the Removable Hindrances which affect the Progress of Chemical Science;" but hindrances of an unusual kind prevented me carrying out my intention. I think Professor Wanklyn has done good service in this direction, by insisting upon experimental investigations partaking of a Quantitative character.

I will, in conclusion, give some illustrations of what has been stated.

(1.) If a liquid does not come through a filter clear and bright (perfectly free from an insoluble solid which is suspended in it) in the laboratory, it is returned to the filter until the pores of the latter are so filled with the solid that the liquid comes through entirely freed from it; the returning of the liquid to the filter several times in order to effect clear filtration is scarcely any hindrance or detriment in a laboratory operation, but imperfect or difficult filtration on the large scale may render a process, excellent in every other respect, unsuitable as a manufacturing operation, if thousands of gallons have to be filtered in the day, more especially if a substance be in solution which is injured more or less by the constant pumping back of the turbid liquid. Years ago a process

was taken out for the purification of sugar solutions, by means of an acetate of lead; after the sugar solution had been filtered to remove from it the precipitate of the impurities produced by the lead acetate; the excess of lead was precipitated by sulphurous acid; the precipitate of sulphite of lead thus formed was almost always in such a finely divided state that no filtering material could be obtained that would filter it bright, except after it had been pumped back three or four times, and even then the liquid rarely came through the filter bright: it baffled the inventor and those who took part in working the process in various places, it had therefore been all but abandoned, and was only worked in one refinery, when I became acquainted with it. I found by altering the conditions that had been followed in a stage anterior to the precipitation of the lead, that it could be precipitated as sulphite in a form sufficiently granular to be separated from the liquid in first filtering it through the filter-bags.

(2.) A student who has worked a week in a laboratory might not only know how to make, but very probably could make, Prussian Blue; but I would like to ask how many professional chemists could make a Prussian blue that would command a good price in the market; a Prussian blue, that when a small quantity of it was mixed with dry white lead, the colour of the mixture would be of a

show that the mere production of an article, even at whatever cost, is not always sufficient; the substance frequently requires to have certain characteristics, which can only be obtained by manufacturing it in a particular manner, and which is generally unknown to professional chemists; these peculiar properties it requires in order to command a profitable sale in commerce, in other words to be a good commercial article. Not many years ago few professional chemists would have been able to tell how Mr. Finzell, the Sugar Refiner at Bristol, was able to turn out of the Vacuum Pan *tons of large well-defined* crystals of sugar in two or three hours; or how in the Island of St. Vincent they were able to produce sugar in large crystals in a few hours from the raw juice boiled in the Gadsden Pan.

(3.) I might cite the manufacture of iodide of potassium in the factory, or the subliming of iodine as it is carried out on the large scale, as other instances in which the process of production in the manufactory is superior to what is known in the professional laboratory. And as examples to the young student, that he may find he will have much to learn in factories, although he may have received a very excellent chemical education.

(4.) I saw Mr. Deacon's beautiful process for extracting chlorine from hydrochloric acid by the oxidation of the hydrogen conducted on a tolerably large scale in the factory; all difficulties

seemed to have been overcome that would prove an hindrance to its adoption when carried out on a still larger scale and *continuously*, but it had not long been in operation under these conditions before obstacles to its being employed as a manufacturing process revealed themselves, which I am not aware have yet been overcome.

But scarcely any new process is adopted as a manufacturing one which does not present difficulties to its adoption, which have not been observed, or have not proved obstacles, on the experimental scale. Far more chemical ability and skill are required to render a process successful on the manufacturing scale, than to carry out an ordinary research in a laboratory; for difficulties which, if not overcome in the factory, would render the process valueless, are either not experienced or are of no consequence in laboratory operations; and in the latter operations, time, quantity of substance obtained from a given amount of material employed, and cost of production, all important factors in a manufacturing operation, have not to be taken into account.

(5.) Davy's investigation into the decomposition of water by the Voltaic current is frequently referred to as a beautiful illustration of the mental faculties which are brought into play when Nature is questioned in a Philosophic manner. After giving some preliminary explanation, I will give it as

Archbishop Thomson gives it, as it will illustrate the method of applying the rules of pure Logic in other cases.

After Cavendish had formed water by passing a current of electricity through a mixture of hydrogen and oxygen, it was found that a current of Voltaic electricity decomposed water, the chief products of the decomposition being hydrogen and oxygen, but it was also observed that an acid and alkali were also products, the former collecting around the *positive*, and the latter around the *negative*, pole of the electrical combination. There was a difference of opinion as to the nature of the acid and alkali. The question remained in this state when Davy commenced the investigation: he believed that water consisted solely of oxygen and hydrogen gases, and therefore the acid and alkali were adventitious products; and he set to work to obtain the required proof by experiment.*

* As the Archbishop has not introduced all the experiments, I will supplement his statement in this respect. The two glass tubes Davy employed in his first experiments were connected together by an animal membrane. On immersing the poles of the battery in their respective tubes, he found, besides the gases hydrogen and oxygen, a fixed alkali in one tube and muriatic acid in the other. He came to the conclusion that the acid and alkali were produced from the common salt in the animal membrane. He therefore substituted for it well-washed *cotton fibre* for connecting the glass tubes. He found by this substitution that muriatic acid no longer appeared, but there still appeared the fixed alkali and an acid. Thinking the alkali might come from the glass, he substituted agate for it, and pure amianthus for the cotton. As the acid and alkali

"I. Statement of the case, the *residual* cause being still undiscovered.

'The decomposition of water by electricity produces oxygen and hydrogen, with an acid and an alkali.'

II. Separation of the *residual* from the principal cause.

a. 'The decomposition of water produces oxygen and hydrogen.'

b. 'The production of an acid and an alkali in the decomposition of water *may be caused* by action on the glass vessel containing the water.' (Problematical Judgment,—A.)

III. The latter Judgment—*b.*—disproved by a syllogism in Mood EAO, Fig. iii., with a conclusion that *contradicts* it.

'A case in which I employ a vessel of gold cannot involve any decomposing action on a glass vessel.

'A case in which I employ a gold vessel still gives the acid and the alkali;

'Therefore cases of the production of the acid and alkali are not always cases in which glass is decomposed.'

IV. Another attempt to suggest the residual cause.

'The acid and alkali are produced by the decomposition of impurities in the water employed.'*

Syllogism in AAI, Fig. iii., *tending* to prove this.

'An experiment with *distilled* water must admit less impurity,

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* Davy, when he found the acid and alkali still appeared after employing the cups of gold, thought they must come from the impurities in the water he employed. He therefore evaporated one quart in a silver basin, and obtained seven-tenths of a grain of dry residue. He therefore repeatedly distilled the water from a silver alembic until it contained no residue. On making the experiment with this pure water an acid and alkali again appeared; but it was the volatile alkali, not one of the fixed alkalies, and the acid

'An experiment with distilled water gives less acid and alkali;

'Therefore sometimes with less impurity we have less acid and alkali.'

V. 'The contact of moist hands' may be an additional cause of the residual phenomenon.

Improved syllogism in AAI, Fig. iii., to include this concurrent cause.

'An experiment with distilled water and apparatus kept from contact of hands will admit *still less* impurity,

'An experiment, &c., results in the production of still less acid and alkali;

'Therefore sometimes with still less impurity we have still less acid and alkali.'

VI. Amended syllogism, AAA, Fig. iii.

'A case where we use these precautions *in vacuo* is a case of *no* impurity,

'A case where we use, &c., *in vacuo* is a case of *no* acid and alkali;

'Therefore a case of no impurity is a case of no acid and alkali.'

VII. Immediate inference from last conclusion.

'Cases of no-impurity are cases of non-production of acid and alkali,

'Therefore' (according to the example in Division II. of inference from A)

'All cases of production of acid and alkali are cases of some impurity;'

Which was to be proved."

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was nitrous acid. He thought the nitrogen required for the production of both the acid and alkali came from the air dissolved in the water; he therefore finally boiled the water to expel the air it contained, and conducted the experiment in an atmosphere of pure hydrogen; that was the crowning point of his discovery, for no

Chemistry as long as it is taught by the present methods will never prove of any value in after-life to those who study it as a branch of general education; it will only prove of value to those who study it as a profession, and even the latter might become sooner and better acquainted with it than at present. But I contend that even those who only study it as a branch of general education ought to, and would, be able, if it were taught in a rational manner, to make use of it in after-life, as they can arithmetic and the other subjects they were taught at school. But by the present system a multitude of disconnected facts are tumbled into the learner's mind; the majority they will never remember, and the rest will be mere lumber, for they will prove of no practical use. What the general student requires to know, and what the teacher ought to impart to him, is a general knowledge of the science, a knowledge of its leading links, a knowledge not superficial but thorough, so as to have a true conception of the subject in its great features, leaving the study of the minor details to those who are to employ it in some special avocation in the future.

LECTURE VI.

On the Teaching of Qualitative Analysis in Secondary Schools —A valuable Study for Disciplining the Mind when taught in accordance with the Laws of Thought—What can be accomplished in Teaching Boys Chemistry, and to what extent it can be carried on in Secondary Schools—The After Effects of a Sound System of Chemical Instruction in Schools—The Cost of Teaching it in Schools—The Difference between Exact Knowledge, though limited in extent, and Superficial Acquirements illustrated—Cardinal Newman on the Teaching of a Multitude of Subjects—Smatterers in Science most Injurious in Industrial Establishments — On Technical Language — Popular Science Lectures.

If the study of Chemistry is pursued beyond teaching what is termed Elementary Chemistry, and which has been described in the last Lecture, *qualitative analysis* is the next branch of the science now all but universally taught in schools of general education as well as in schools or colleges of science. If teachers of the science were asked with what object this branch was taught in schools, they would, if they were guided by the way that most books on the subject are written, almost invariably answer to teach the boys how to *test* or *analyze* substances. It would rarely be stated: "I am afraid that the reason for making it a

branch of general education is, or ought to be, that it forms such an admirable discipline for the mind when taught in accordance with the laws of thought."

Most of the boys who are taught Chemical Analysis in schools will never have any occasion to make an analysis in after-life. The object of the study ought to be, as that of all other school studies, to assist in training and developing the mind; and the system of instruction which best accomplishes this is the best for teaching the subject itself.

No school, still less a college, which professes to *educate* ought to employ the mere *testing* books; and the books of Tables are not much better; for the system is purely mechanical, for by directing all that has to be done, by telling this and showing that, the learner is made a mere recipient; it takes away from him the necessity for, or rather prevents him, exercising his judgment, and it relieves those teachers who are not earnest in the work of instruction of the most essential part of their duties, for the analytical tables alluded to allow teachers to adopt that "repeating by rote system," in another form, which is yet far too prevalent in our schools. The Giessen outlines and Fresenius are excellent, especially the latter, as reference books; but the plan on which they are constructed does not

books, and the attenuated copies of them which are now appearing can only perform one office for the learner—they can *cram* him for an examination.*

In qualitative analysis we have, in my opinion, a most valuable instrument, not only for training the mind, but for teaching the science, independent altogether of its value of enabling one to ascertain what elements are present, and in what state of combination, in any unknown compound or mixture. Of all the reforms the late Baron Liebig introduced in the teaching of the science, the most valuable one, I believe, was the systematic course of qualitative analysis which formed an essential part of the plan of teaching pursued at Giessen. The old method of teaching consisted in setting the student to work at quantitative analysis as soon as he entered the laboratory. An eminent chemist informed me some years ago that when he entered, as a student, an English laboratory, the first thing he was set to do was to estimate the quantity of copper as oxide in a given quantity of sulphate. The Assistant afforded him assistance in the precipitation, and, having given him a filter, told him to throw the precipitate upon it. The student, without more to do, spread the filter upon

* Mr. Spencer Baynes, in his preface to the Port-Royal Logic, observes, "In reading over the book again, I have been struck afresh with its special fitness to serve as a text-book in the work of higher instruction. While one of the worst books for *cramming*, it seems to me to be one of the very best for educating the mind."

the *table*, and then threw the precipitate upon it. The incident was narrated in a conversation we were having on the *past* and the *then present* modes of teaching the science. But oxide of copper to be selected as the first substance the student was to estimate did not of itself exhibit an enlightened knowledge even as regards teaching quantitative analysis.

In the prosecution of other branches of Chemistry besides analysis, the mental faculties required for observing and for conducting experiments correctly are brought into play, but in none is the mind so constantly occupied with that of separation and comparison; this mental act progressing with the student's progress in the study from its most rudimentary form to its highest manifestations, that of JUDGMENT, REASON, SCIENCE, as qualitative analysis *when intelligently taught and cultivated.*

In every analysis the different elements composing the substance under examination are first classified by the analyst into groups; this involves abstraction and generalization. And in this classifying, and in the questions which the analyst asks the substance, as it were, by means of his reagents, and in interpreting correctly the positive and negative answers he receives to his questions, two at least of the four methods of experimental inquiry given in Mill's System of Logic are employed.

As qualitative processes occupy less time for

their performance than quantitative ones, qualitative analysis is, for that very reason alone, better adapted as a course of instruction in general education than quantitative analysis; independent of its many other advantages over the latter. The rapidity with which qualitative analysis can, compared with quantitative ones, be executed, even if qualitative had not to precede quantitative examinations of all substances whose nature and composition are unknown, renders that method of analysis far superior to the other for making the student acquainted, in a given time, with the physical and chemical properties of a large number of substances; for whilst a very complicated mixture of substances can be qualitatively examined in seven or eight hours by an analytical student of six months' standing, it would require a very much longer training to execute a correct quantitative analysis of the same mixture, and the time occupied in its execution would be at least as many weeks as it took hours to examine it qualitatively.

A knowledge of the properties of the largest number of the compounds of the elements included in the analytical course, and as extensive an acquaintance as possible with the properties of the compounds, ought to be the teacher's aim for his students to acquire. By such a course of teaching not only would the student acquire an exact and most extended acquaintance with chemical facts

and principles, but he would at the same time become a most expert and proficient analyst. But a knowledge of the science, so extensive and profound, cannot be obtained, if the analytical Tables I have already alluded to are employed for teaching the student analysis; under that system he can only go on in the same groove day after day. Such a comprehensive course can only be pursued when a philosophical plan of teaching is adopted, one by which the student is taught, *from the first lesson to the last*, to discover for himself the analytical processes he adopts. Such a plan I will presently explain, and also its beneficial effects both on boys and young men.

I also believe that when qualitative analysis is taught in the thorough manner I have named, it prepares the student more efficiently for original investigations both in the laboratory and factory, than any other mode of studying the acquired portion of the science which has yet been devised. For an analysis is an investigation; it differs of course in essential respects from a thoroughly original investigation; by that I mean when the investigating ground has not been explored by any previous investigator; but when it has, investigations of that kind, and the perfect execution of a complicated qualitative analysis, do not differ so much in the skill, knowledge of the science, and ability required for their successful prosecution as

might be supposed. For if the substances students have to analyze are *artificially prepared*, which is part of Liebig's plan, the difficulties—as the student progresses—can be increased, not only by increasing the number of substances in the mixtures to be analyzed, but in many other ways. The superiority in a variety of ways of *artificial mixtures of substances*, *over minerals* or *other natural substances*, is, for beginners, very great, although it may not appear to those who have given little thought or attention to the teaching of analytical science.

Many years ago I accepted the post of teacher of Chemistry at Queenwood College, Hampshire; the College at that time comprised a boys' school, and an Agricultural College, the Agricultural pupils were all young men; most of the boys, as well as the young men, were instructed in Chemical Analysis in the laboratory. When I entered upon my duties I found the book in use was the Giessen Outlines, and to my surprise and discouragement I found both the boys and young men had a great dislike to the study, they would all avoid if possible attending the laboratory classes. One of the boys explained to me the reason one day; he said, "We can make the analyses, but we do not understand what we are doing, and therefore we do not like the subject." Having made

which beset me, I set to work to see if they could be overcome. I had seen the Giessen Outlines used with comparative success in the College of Chemistry in London; then why did it not answer here? for it was evidently the method that proved unsuitable for the conditions under which the science had to be taught in this institution. In the London College the students' whole time was given to the study of the science, and they were all young men who were pursuing the course of study for some immediate object in view; and it is truly astonishing how some young men under these conditions can be got to "plod and toil," even when they are taught in such a way that no glimpse of the reason why they do this and that is revealed to them by their teacher; the so-called learning the subject being a system of drudgery from the beginning to the end. But boys, especially if intelligently taught in other subjects, will not work on such a mental treadmill, or at least not willingly; you must make them understand the subject which you wish them to learn, for them even to be attentive, not to speak of their taking a pleasure in the study.

Another difference in the conditions was, that only three or four hours in the week could be given to the study of the science in the Hampshire Institution, and therefore the imperfections in the system which could be overcome, with the

aid of an excellent teacher like Dr. Hofmann, when the student's whole time was devoted to the study, were at once apparent under the altered conditions, and rendered the science a distasteful study to both classes of pupils.

Without going too much into detail, I may state I adopted a plan of so arranging the experiments the student had to make on the members of each group of substances that he could, after making the experiments, distinguish for himself what chemical properties they had in common, and what properties distinguished each memberfrom the others composing the group. By thus teaching the pupil himself to COMPARE, DISTINGUISH, JUDGE, he became an intelligent and active DISCOVERER,* for he discovered himself the methods for separating and detecting the different members in each group,

* The late Mr. Charles Babbage, in his letter to the Society of Arts on Industrial Instruction in 1853, very truly observed:—"I have long been convinced that education, at least in England, is scarcely advanced beyond its infancy, as an art. The pupil usually looks forward to his task as a bore, and would gladly avoid the acquisition of much that is forced upon his attention. That the acquisition of knowledge should necessarily be accompanied with disgust, is directly at variance with the experience of all who have themselves enlarged its boundaries. Nothing is more exciting than the pursuit of those laws by which Nature organizes the world we inhabit; and, after endless disappointments, nothing gives more permanent pleasure than the knowledge of those laws, which industry and genius have thus enabled us to detect. It is the triumph of the *acquisition*, through the successful exertion of our own faculties, which gives zest to our enjoyment; *and that enjoyment might, by proper modes of instruction, be raised in the*

and so throughout the entire analytical course. But this plan possesses other important advantages over any other. It exhibits a like progression to the mind; it begins with a few subjects, and successively adds to them until the entire system is reached; it proceeds, in short, from the simple to the complex. The effect of this change made the study most fascinating to both classes of pupils, the boys would gladly spend the hours they might devote to play to study in the laboratory, and the young men also gladly devoted their spare hours to the study of the science. So complete was the change of feeling amongst the pupils, that if it became known during the time the boys were on the playground I had engaged to take for some other teacher his class in my own subject, loud joyous sounds would be *breast of the youngest student, as certainly as in that of the most profound philosopher.*

"For this purpose, however, it is necessary that the teacher should be a master of his subject, and have very accurate knowledge of the capacity and the state of information of his pupil. He must then be able to divide or break up the subject which he teaches into stages, of such a degree of simplicity, that the pupil shall, by his own apparently unaided efforts, be himself able to make the greater part of the proposed steps.

"*That a large part of the student's acquisitions would be accompanied by much of that delight which ever attends original investigations.*

"The *talents* that might be *developed*, and that are *required*, in *such instruction*, are of the highest order; but the miserable payments that are made for teaching effectually prevent their appli-

heard.* Although only about four hours in the week were devoted to the study of the science, boys of fourteen or fifteen years of age became ex-

* "A few paragraphs must be added in further inculcation of the two general principles that are alike the most important and the least attended to—namely, the principle that throughout youth, as in early childhood and in maturity, the process shall be one of self-instruction; and the obverse principle, that the mental action induced shall be throughout intrinsically grateful. If progression from simple to complex, from indefinite to definite, and from concrete to abstract, be considered the essential requirements as dictated by abstract psychology; then do the requirements that knowledge shall be self-mastered, and *pleasurably* mastered, become tests by which we may judge whether the dictates of abstract psychology are being obeyed. . . . . For manifestly, if the steps in our *curriculum* are so arranged that they can be successively ascended by the pupil himself with little or no help, they must correspond with the stages of evolution in his faculties; and manifestly, if the successive achievements of these steps are *intrinsically gratifying to him*, it follows that they require no more than a *normal exercise of his powers*. . . . . Observe, again, that this discipline necessitates a continuous organization of the knowledge he acquires. It is in the very nature of facts and inferences assimilated in this normal manner that they successively become the premises of further conclusions—the means of solving further questions. The solution of yesterday's problem helps the pupil in mastering to-day's. Thus the knowledge is turned into faculty as soon as it is taken in, and forthwith aids in the general function of thinking—does not lie merely written on the pages of an internal library, as when *rote-learnt*. Mark, further, the moral culture which this constant self-help involves. COURAGE in attacking difficulties, PATIENT concentration of the attention, PERSEVERANCE through failures—these are the *characteristics* which after-life specially requires; and these are characteristics which this system of making the mind work for its food specially produces. . . . . Similarly with the correlative requirement, that the method of culture pursued shall be one productive of an intrinsically happy activity—an *activity not happy because of extrinsic rewards to be obtained, but*

cellent analysts. Those of them who, on leaving the school, became pupils with surgeons, could make medical, food, and other analyses more accurate in every respect than the surgeons to whom they were articled; and they found on attending the London Medical Schools, three or four years afterwards, that the chemical instruction they had received in Hampshire was much more perfect and extensive than that given in those Schools. They found on coming to London that they had this science thoroughly studied, as far as was required for their medical course and degrees.

Three important questions will naturally occur to those who have not had to do with the teaching of the science in schools, and which they would as naturally desire to see answered:—

1st. Are the same or different methods employed in teaching the elements of the science in Germany, &c., as in these countries? Much the same methods are pursued, and I can state, from having had to teach pupils who had been taught the elements of the science in secondary schools in Austria, Germany, Switzerland, and France, that I found they were in no way superior in knowledge of the subject to the like class of pupils in our own country. The advantages continental nations, especially Germany, possess over our own, is in the teaching of the science in the higher schools or colleges; and in the longer time students can afford

to give to the study of it, as I have noticed in the first Lecture. But even in the best schools in Germany every student does not, just as in our own, turn out a success; and this may, in a great measure, be due to their not being properly trained at the commencement of their studies, so as to render the knowledge they acquired *organized knowledge.* If we were to take the important step of having all that can be taught of the science in our general schools, *thoroughly* taught by the most philosophical methods; our higher schools and colleges, both as regards *pure*, and *applied*, science might soon equal the best in Germany.

2nd. Was it found that the teaching of Chemistry interfered with the prosecution of the other studies of the school, either as regards the time that had to be devoted to the study of it; or, after the pupils took a delight in the study, by its *unduly* absorbing their attention? Some of the other teachers assured me that after the pupils took an interest in the study of it, their interest in their other studies increased; and this was only natural, for as Professor Henslow found (*see* Note, page 78), the study of it increased their general intelligence.

3rd. What would be the cost of instructing pupils in the course of practical Chemistry you have sketched out? There must be a room fitted

ing of Chemistry; after the laboratory has been fitted up with benches, and it has been furnished with the needful quantity of bottles and chemicals; the entire cost of which need not exceed £50; the cost of the apparatus and chemicals for each student, studying the number of hours stated each week, ought not to cost more than from 7*s.* 6*d.* to 10*s.* for a session of nine months, and this sum would cover also the cost of all reasonable breakage. I know from actual experience it can be taught for the amount named.

If the teaching of this science were so carried out in our secondary schools it would at once compel a higher class of instruction to be given in this, and the other Inductive Sciences, than is given at the present time, in our Universities, Colleges of Science, Medical Schools, and Technical Colleges. The benefits that would accrue to Science, Medicine, and Industries based on Science, from such a reform in education it might be prudent not to state, even if it could be foretold; or at least it might be better to understate the effects than to state correctly what could be attained, as George Stephenson did about railways; he calculated the average speed of a train at ten miles an hour, because if he had estimated it higher, the so-called practical men of that day would have turned a deaf ear to him, as that most unsafe character in their estimation, an enthusiast and a visionary.

But the teaching of Chemistry in secondary schools might now be carried out even further than I then accomplished at an expenditure of three or four hours in the week for a period of two years. For considerable progress might now be made in quantitative analysis owing to the simplification of many processes by the substitution of volumetric for gravimetric ones, and also the simplification of many gravimetric operations, especially if a well-devised method were framed. I hope shortly to publish a scheme for accomplishing this object; it will be one that will as efficiently prepare the student for extended quantitative analysis, as the plan "system of bottles," invented by Liebig, prepares for "complex" qualitative ones. This extension of Practical Chemistry would be of great value in all schools where only a limited time could be devoted to the study, especially in the secondary schools of science, whether day or evening.

I have always found my system superior to any other when both have been tried and tested by the unerring standards inculcated by the late Mr. Charles Babbage and Mr. Herbert Spencer (*see* Notes, pages 260 and 262). I will name two more instances as examples in addition to the one I have given. When I commenced to teach at Putney College, most of the students, as soon as I commenced, forsook the Chemistry classes, as they thought

I would not be equal to my predecessors. I had sufficient confidence from what I had done in Hampshire to believe that if I could only retain the few who came to me for a fortnight, they would all return. What I expected not only occurred, but, when the institution came to be broken up a short time afterwards, they all came forward to ask me to allow them to take a laboratory for me in London, and furnish it for me, and they would come and be my pupils, and I was to charge them the same fees as if they had not done anything; of course I could not consent to such a handsome and generous offer. When I entered on my duties at the latter end of 1856, at the Museum of Irish Industry, I had to start without a *single day student*, for there had not been any for some years. In a short time I had a good class, and what my evening students accomplished I shall mention in the eighth Lecture, to show what evening schools and colleges might effect. But to show that I am not overstating matters I will give one passage from an article in the *Dublin Medical Press* (Jan. 28, 1863), on some investigations some of my students had published :—

"We cannot conclude this notice without a word in praise of the institution, which, through its Professor of Chemistry, Mr. Galloway, confers chemical instruction of the sound and practical

like this. We have so often had occasion to express in these columns our views as to the utter incapability of the plan upon which Chemistry is usually taught to give to any but the enthusiastic and untiring student anything but the most incoherent, and, for all practical purposes, useless smattering of the science, that we shall not now go into that subject, but it cannot but be a source of congratulation to the citizens of Dublin generally, and to our readers in particular, to whom the question of imparting sound scientific education is a matter of the highest importance, that our metropolis now possesses a Chemical School not second in standing to any in London, or even to the famous educational laboratories of the Continent."

It will not be inappropriate here to notice the difference between the two kinds of knowledge, the exact and superficial, especially as my object in writing this book is to improve the methods of teaching the Inductive Sciences, so that the *majority* of students will, in place of the *verbal* (superficial) knowledge that is acquired at present, acquire *exact* and *solid* knowledge in these subjects, however limited and elementary it may be. The possessor of *exact* knowledge of any subject, however limited it may be in extent, has at least arrived at "instructed ignorance;" he knows where his knowledge ends, and his ignorance commences,

and can, if so disposed, or the necessity arises, make further progress, for he has a *good foundation* of exact and solid knowledge whereon to build. Professor Virchow, in his admirable address, "The Freedom of Science in the Modern State," remarks :—"I myself, for example, have honestly laboured all my life to acquire a knowledge of Chemistry ; I have worked in the laboratory ; but I feel by no means competent at once to take my place in a conference of chemists, and to discuss modern Chemistry in all its bearings. Nevertheless, I am qualified, with some little time, to bring up my knowledge to such a state, that I should find no new discovery in Chemistry to be incomprehensible. But I am obliged to work up this knowledge anew for each occasion. I do not possess it already, and if I want to use it, I must first obtain it. That which is my accomplishment is just the *knowledge of my ignorance.* The most important thing is, that I know exactly what I do *not* understand in Chemistry. Did I not possess that knowledge I should be *always oscillating hither and thither.* But since, as I believe, I know pretty exactly what I do not know, I am prepared to say to myself, whenever I am obliged to enter on a field hitherto closed to me, 'Now you must begin to learn ; now you must study anew ; now you must behave as one who is just entering

One who has been superficially taught, unless he has naturally a mind so vigorous that no ill-treatment can permanently enfeeble it, will be unable to acquire sound and exact knowledge; for the foundation has not been laid in his mind, but one the very reverse, on which such a structure can be reared, and the more subjects he has been thus taught, the more enfeebled and dissipated will be his mind. Not a few who have had to submit "to a drudgery so ignoble, a mockery so contumelious," as this sort of so-called education, cease to have any desire for knowledge, and, in fact, look upon it with detestation.

Others who have been so educated continue on through life in much the same way, ever apparently learning, but never *acquiring* knowledge; this class of persons form the bulk of the audiences at popular lectures, they are ever attending these kind of lectures on every variety of subjects, mistaking *diversion* for *education;* they remain smatterers to the end of their lives. "They see objections more clearly than truths, and can ask a thousand questions, which the wisest of men cannot answer; and withal they have a very good opinion of themselves, and are well satisfied with their own attainments; they know not their own shallowness." The poet was right when he said "a little learning is a dangerous thing," he was alluding to the

A very learned and distinguished man * has thus expressed his views upon the superficiality which is produced by that ambitious system of education which is now so rife: "Nor indeed am I supposing that there is any great danger, at least in this day, of over-education; the danger is on the other side. I will tell you, Gentlemen, what has been the practical error of the last twenty years—not to load the memory of the student with a mass of undigested knowledge, but to force upon him so much that he has rejected all. It has been the error of distracting and enfeebling the mind by an unmeaning profusion of subjects; of implying that a smattering in a dozen branches of study, is not shallowness, which it really is, but enlargement, which it is not; of considering an acquaintance with the learned names of things and persons, and the possession of clever duodecimos, and attendance on eloquent lecturers, and membership with scientific institutions, and the sight of the experiments of a platform, and the specimens of a museum, that all this was not dissipation of mind, but progress. All things now are to be learned at once, not first one thing, then another, not one well, but many badly. Learning is to be without exertion, without attention, without toil; without grounding, without advance, without finishing. There is to

* Cardinal Newman, "On Knowledge Viewed in Relation to Learning."

be nothing individual in it ; and this, forsooth, is the wonder of the age. What the steam-engine does with matter, the printing-press is to do with the mind ; it is to act mechanically, and the population is to be passively, almost unconsciously, enlightened, by the mere multiplication and dissemination of volumes. Whether it be the school-boy, or the school-girl, or the youth at college, or the mechanic in the town, or the politician in the Senate, all have been the victims in one way or other of this most preposterous and pernicious of delusions. Wise men have lifted up their voices in vain ; and at length, lest their own institutions should be outshone and should disappear in the folly of the hour, they have been obliged, as far as they could with a good conscience, to humour a spirit which they could not withstand, and make temporizing concessions at which they could not but inwardly smile."

The Rector of Lincoln College, Oxford, in a Paper, "Philosophy at Oxford," which appeared in *Mind* (1876), observes : "Another and a weighty inference, which is secretly undermining not only philosophical thought, but the genuineness of all study among us, remains to be noticed. This is the false direction of elementary teaching given to it *by the system of honours and prizes.*

"It is sometimes thought that there is an essential connection between progressive knowledge and

teaching. Beginners inevitably think so, for every beginner finds himself helped by going over and over the elementary ground. But after progress has reached a certain point, to be constantly dwelling upon the alphabet of the science, ceases to be a function of the understanding, and becomes mechanical routine. Now the prize-system as worked by us is a system under which the pupil is carefully excluded from contact with progressive knowledge, or knowledge in a state of movement and fermentation.

"That teaching is not *per se* destructive of the love of knowledge may be admitted. It is sufficient to turn to the precedent of Germany in the last generation. . . . . But among us there is a zeal of teaching which is not inspired by progressive knowledge. The whole of the literary and philosophical teaching in Oxford is in the hands of young men—the tutors of the colleges. . . . . The young teacher is an honour-man and a prize-man; *voilà tout!* and he knows the sure road to make others win honours and prizes, the road by which he himself won them. Even if he has better aspirations, he must not indulge them. He is embarked on the career of teaching, at twenty-five, say; and he finds himself at once the slave of a great teaching-engine, which drives him day by day in a round of mechanical work. There is no stepping aside; if you fall out of the ranks, you

perish. . . . . The teacher must not lose a moment in teaching a subject, in searching out its foundations, in inspiring his pupils with a love for it, with a desire to pursue it in a spirit of thoroughness. He must crowd into the year and a half of preparation a miscellaneous assortment of ready-made propositions upon the leading topics of philosophy, history, politics, and literature. *Our system has gradually become one which carefully excludes thoroughness. It is the exaltation of 'smattering' into a method.* If the teacher goes about to *give instruction* in a subject, the pupils fall away from him. Their instinct tells them that time so spent is time lost. Hence the prize-student never goes near the Professors. . . . . What the aspirant for honours requires is a *répétiteur*, who knows the 'schools,' and who will look over essays for him, teaching him how to collect telling language, and arrange it in a form adequate to the expected question. It soon becomes indifferent to the teacher on what subject he lectures. The process for training for the race is the commanding interest. Training, be it observed, not intellectual discipline, not training in investigation, in research, in scientific procedure, *but in the art of producing a clever answer to a question on a subject of which you have no real knowledge.* . . . . . For two years the pupil is thus forced along a false road of study in which neither

science nor philosophy encounter him. Memory is really almost the only faculty called into play. Were they facts with which the memory is thus charged, the inadequacy of the system would be apparent at once. But in the preparation for this examination, instead of facts, the memory is charged with generalized formulas, with expressions and solutions which are derived ready-made from the tutor. The first principle of philosophical, nay of intellectual, training, viz., that all should be educed from the pupil's own mind, is here inverted; all is poured into him by his teacher. *The teacher does as much*, and *the pupil as little, as possible.*" A by no means flattering description of the state of education in one of our great Universities.

A smattering of any subject must act injuriously on the person who has acquired this deceptive kind of knowledge; but a smattering of science may, and often does, prove more injurious to others than to the smatterer himself; from the practical experience I have had in different branches of manufactures, I can state most unhesitatingly, that not a few manufactures have been injured by incompetent managers, men who had got a smattering of the science on which the industry was based, and who, by talking a scientific jargon, concealed their ignorance from, nay, who were generally clever enough to make the gibberish appear profound

scientific knowledge to the minds of the owner or directors of the industry, who were unacquainted with science. This class of men are for ever promising they will, as soon as this piece of machinery has been got, or some new arrangement has been made, or some different chemical has been obtained, bring about unheard of and priceless miracles in the industry; they themselves sometimes perceiving that they are carrying on the business to destruction, but dare not express it to their employers for fear that some one of intelligence would be consulted, who would expose the sham, and denounce the impostor; I will again allude to this most important subject when discussing technical education; but I may here state that it is highly probable that many of these incompetent men, who seek employment in factories, are themselves victims of a defective system of scientific teaching, that defect being sometimes heightened by having had a charlatan as a teacher.

At all events, this is quite certain, that if sound and exact scientific knowledge, however limited in extent, were substituted for what is inexact and superficial, our manufacturing industries would cease to be injured through incompetency. But if this most desirable change in scientific education were to take place, not alone would our industries benefit, but our young men who become Civil

such as the West Indian Islands, might not only be even more serviceable, than at present, in the parts of the empire in which they resided, but in many cases to that of the empire at large. But with the change in the teaching of the Inductive Sciences, must come a change also in the examinations of these sciences. They are, at present, almost, if not entirely, mere paper examinations; we shall, therefore, bring under review examiners and examinations in the next Lecture.

Before concluding I will make a few observations on the language of science or Technical language, and Popular Science lectures. I have already shown in Lecture IV. that it is necessary to objectify our ideas, and that this is done through and by means of language. Now, words when employed in science, unlike their employment in common use, have a meaning steadily fixed and precisely determined; this precision in the meaning of scientific terms necessarily requires, on the part of those who can make *proper use* of them, *accurate habits of thought;* this is an indispensable qualification for attainment in any science; there is no dispensing with it, consequently one who does not know the language of a science, and who has not been taught to think accurately with respect to it, cannot understand *properly* what may be told or shown him about the facts or principles

to a young man whose education had been neglected, amusingly remarks on this difficulty when referring to the Kantean terminology, "in assigning," he says, "to the complex notion X the name *transcendental*, Kant was not simply transferring a word which had previously been used by the schoolmen to a more useful office ; he was bringing into the service of the intellect a new birth ; that is, drawing into a synthesis, which had not existed before *as* a synthesis, parts or elements which exist and come forward hourly in every man's mind. I urge this upon your attention, because you will often hear such challenges thrown out as this (or others involving the same error), 'Now, if there be any sense in this Mr. Kant's writings, let us have it in good old mother English.' That is, in other words, transfer into the unscientific language of life scientific notions and relations which it is not fitted to express. The challenger proceeds upon the common error of supposing all ideas fully developed to exist *in esse* in all understandings, *ergo*, in his own ; and all that are in his own he thinks that we can express in English. Thus the challenger, on his notions, has you in a dilemma, at any rate ; for, if you do not translate it, then it confirms his belief that the whole is jargon ; if you *do* (as, doubtless, with the help of much periphrasis, you may translate it into English, that will be intelligible to a man who already understands the

philosophy), then where was the use of the new terminology? But the way to deal with this fellow is as follows:—My good sir, I shall do what you ask; but before I do it, I beg that you will oblige me by—1. Translating this Mathematics into the language of Chemistry; 2. By translating this Chemistry into the language of Mathematics; 3. Both into the language of cookery; and, finally, solve me the Cambridge problem, 'Given the captain's name, the year of our Lord, to determine the longitude of the ship.' This is the way to deal with such fellows."

The Ideal conceptions scientific men form with respect to discoveries in science and the particular form of words (Technical language) they employ for communicating to other scientific men their conceptions, cannot of course be understood in their true and real sense by non-scientific minds; if they could, there would be a Popular Road to learning; but this gulf is an impassable one, except by study, to one unacquainted with science. Scientific men cannot bridge over the gulf for the non-scientific by stripping a lecture on any science of the language of that science; for when that is done, it ceases to be science, and can only be, whether by experiments or other aids, an amusement for the hearers. Hence one of the reasons why Popular Scientific Lectures never can be a means of instructing those who neither know

the language of the science, nor yet have any ideas wherewith to connect and blend what they hear, so that it becomes *knowledge* and of a progressive character. And as regards those who, by one form of study or another, are laying the foundation of a science in their minds, popular science lectures, as a rule, will not afford the kind of instruction they require; for a student to be ever dwelling on the alphabet of a science, as on the alphabet of a language, is not wise; and the alphabet of the science a lecturer in popular scientific lectures must confine himself to, *when the majority of his audience know nothing of science*; for he naturally seeks to obtain a large audience, and therefore he must come down to their level; hence he will have to make his lecture more for *seeing* than for *hearing*. And the so-called science that is poured forth by the lecturer is not always of the soundest description; and the experiments shown are said to be sometimes deceptions; but I will let Mr. Todhunter tell the tale:—"So great is the difficulty in persuading experiments intended to be visible to a large company to conduct themselves properly that curious charges of unfairness are in circulation, which are more or less authenticated. Thus it is said one lecturer was accustomed to show by experiment that a body would fall down a tube in the shape of a cycloid faster than down

same vertical height; but in order to assist Nature he was wont to *grease* the ball surreptitiously which travelled on the cycloid. Again, another lecturer was accustomed to illustrate a mechanical principle known by the name of *virtual velocity*; a certain weight ought to remain immovable, though not absolutely fixed; in this case a *nail* applied to the weight, unknown to the spectators, prevented any casualty in the experiment."—*The Conflict of Studies.*

For many years the Government paid several eminent scientific men to give every year in Dublin short courses of lectures on the Sciences they professed; the Government also paid for lectures being delivered in different parts of Ireland; in each case the audiences were what are termed popular ones, for the lectures were free. When I came to work amongst evening students in Dublin, I could find no evidence that these lectures had been of any use in spreading true science amongst the people.

The Manchester people will no longer attend popular lectures, and I look upon it as a healthy sign; they refuse to make Science or any other branch of knowledge any longer a plaything; I hope now that they have put away the toys, they will say, as Professor Virchow says (*see* page 269). Now we must begin to learn, now we must study anew; now we must behave as those who are

LECTURE VII.

Examiners and Examinations—Written Examinations not Suitable Tests for every Subject—Unsuitable Tests for the Inductive Sciences—Distinction between the Deductive and Inductive Sciences—Written Examinations in Chemistry frequently more Defective than they need to be—The Radical Difference between Scientific and Classical Culture—German Opinion on the Evil Effects produced in England by Competitive Examinations—The Evil Effects produced and illustrated when Teaching is rendered Subordinate to Examinations—The Examiner now controls the Teacher—The Great Educational Problem of our Time—The Qualifications an Examiner ought to Possess—The Answers to the Questions frequently require only the Exercise of the Portative Memory—The Preparing of Candidates—Efficient and Inefficient Tests—Cooking on Paper—Examinations in Chemistry applied to Agriculture.

If examinations are employed as tests to ascertain the capabilities of the examinees for particular employments, it is obvious, and will be admitted by every one, that in order to ascertain whether the knowledge the examinees possess is available for the work they seek, the examination test should exactly resemble what they will have to do in the particular avocation they intend to follow. To test a man, whether he possesses the requisite education and capabilities for being

made the best and most suitable test, for writing will be the occupation in which he will be employed. But to examine a man, to see whether he was a good working mechanic by a written examination would be unsuitable, it would be simply absurd; it might be desirable to know whether he could read or write, but the real test, the one that employers would value and accept, could only be applied in the workshop, for it could only there be ascertained whether he had the mental skill to plan and devise, and the manipulative skill to execute.

When examinations were first established at the Universities, a plan not dissimilar in principle was adopted, only such branches of study were examined upon, as the examinee could do or put in practice at the examination just as he would in any future employment of them in the actual business of life, mere information subjects, which do not, like the former, admit of *direct measurement*, were excluded, and it was long before they were admitted as examination subjects.*

* I have endeavoured to show the deteriorating effect which a violently competitive system exercises on the mode in which a great department of knowledge is both taught and studied under its influence. If the results are such as I have described them in the case of the particular instance selected, that of the exact sciences, there arises immediately a strong presumption that, in other branches which form the subjects of honours' examinations, the evil will be still more serious. Of all bodies of permanently acquired truth, the sciences of demonstration, by their very struc-

Pen, ink, and paper are the instruments, in addition to books, which students of languages, and of the Deductive Sciences, require for the prosecution of their studies in these subjects; the student's power of doing or putting in practice that which his study intends he should be able to do, as working out problems, translating dead languages, for instance, can therefore be more practically and fairly tested in these subjects by written examinations than other subjects.

But written examinations are not suitable tests for the Inductive Sciences; as pen, ink, and paper, as well as books, are subsidiary instruments in their cultivation; to acquire a knowledge of them the student must not simply know what has been said and done by others in these subjects, but he must himself study the productions and operations of Nature, in the laboratory or in the field; and it is there only that he can be satisfactorily and efficiently examined as to whether his knowledge in these subjects is a knowledge of things and not the *names* of things.

When written examinations are employed as

ture, afford the smallest field for the exercise of mere memory. Subjects like philology, history, moral philosophy, and natural science, on the contrary, when forming the matter of competitive examinations, almost inevitably play into the hands of the recollecting faculty, and are, therefore, likely to be more rapidly and deeply deteriorated under the stimulus of competition than are the exact sciences."—Mr. SEDLEY TAYLOR, M.A., *On the Endowed*

tests of a student's attainments in the Inductive Sciences, these subjects are converted almost completely into mere information subjects; for by no written examination of any kind can it be ascertained whether the examinee has been trained and possesses the mental qualifications necessary for being a GOOD OBSERVER and EXPERIMENTER, and whether he has even acquired the necessary manipulative skill for the latter; and yet observation and experiment are *the fountains* of the Inductive Sciences, they are the *two* sources from which springs our knowledge of Nature and its laws. Scientific observation, although it is, as we have previously shown, a less advanced stage than experiment, is most difficult, "it requires a cultivated, sober mind, and a well-schooled experience, which is only acquired by long practice." The art of observing, states Liebig, is like a piece of glass destined for a mirror, which requires to be polished with the utmost care, to produce the reflection of a clear and undistorted image; and every experiment, he observes, is a thought rendered perceptible to our senses. The late Sir John Herschel has well pointed out the distinction between the Deductive and Inductive Sciences:—"Into abstract science the notion of cause does not enter. The truths it is conversant with are *necessary* ones, and exist independent of *cause*. But in natural science *cause* and *effect* are the ultimate relations we con-

template; and *laws*, whether imposed or maintained, which, for aught we can perceive, might have been other than they are. This distinction is very important. A clever man, shut up alone and allowed unlimited time, might reason out for himself all the truths of Mathematics, by proceeding from those simple notions of space and number of which he cannot divest himself without ceasing to think." But he could never tell, by any effort of reasoning, of what elements sugar is composed, that it would have a sweet taste, or that it would dissolve in water; or why some substances containing nitrogen, as one of their elements, should be violent poisons; whilst other substances containing the same element are the most nutritious of our food substances, the organic portions of our bodies being chiefly built up of them. Neither could he tell why *a very volatile liquid* should be produced by the union of the *two solids*, carbon (charcoal) and sulphur; or why *a liquid*, water, should be formed by the union of *two gases*, hydrogen and oxygen.

As observation and experiment are the sources of our knowledge of the Inductive Sciences, they are the most important and indispensable qualifications a student of these sciences ought to possess; a system of examination, in which he cannot be tested as to whether he possesses these qualifications or not, is clearly a most inefficient and defective one.

Written examinations in Chemistry are even more defective, in my opinion, than they need be; the questions given seldom requiring the exercise of the reasoning powers, as they admit of being answered by the exercise of only the mechanical or portative memory. The effect of examinations of this kind will be pointed out as we proceed. Professor Tait, no mean authority, believes, as we shall see, that examinations, conducted as they too often are, are the most imperfect of human institutions.

The question whether the Inductive Sciences are capable of being made subjects of competitive examinations is brought prominently forward in the following extract from Professor Cook's work on Scientific Culture :—

Professor Cook, in addressing a body of students at the Harvard University, said :—"When advocating in our Mother University of Cambridge, in Old England, the claims of scientific culture, I was pushed with an argument which had very great weight with the eminent English scholars present, and which you will be surprised to learn was regarded as fatal to the success of the natural science *triposes* then under debate. The argument was, *that the experimental sciences could not be made the subjects of competitive examinations.* Some may smile at such an objection; but, as viewed from the English standpoint, there was really a great

deal in it, and the argument brought out the *radical difference* between scientific and classical culture.

"The old method of culture may be said to have culminated in the competitive examinations of the English Universities. We have no such examinations *here*. Success depends, in competitive examinations, not simply on knowing your subject thoroughly, but on having it at your fingers' ends, and those fingers so agile that they can accomplish not only a prodigious amount of work in a short time, but can do this work with absolute accuracy. For the only approach we make to an experience of this kind, we must look to our athletic contests. It may, of course, be doubted, whether the ability, once in a man's life to perform such mental feats, is worth what it costs. Still it implies a very high degree of mental culture, *and it is perfectly certain that the experimental sciences give no field for that sort of mental prize-fights.* It is easy to prepare written examinations which will show whether the students have been faithful to their work, but they cannot be adapted to such competitions as I have described without abandoning the true object of science culture. The ability of the scientific student can only be shown by *long-continued work* at the laboratory table, and *by his success* in investigating the problems which Nature presents.

"We have here struck the true key-note of the

scientific method. The great object of all our study should be to study Nature, and all our methods should be directed to this one object. This aim alone will ennoble our scholarship as students, and will give dignity to our scientific calling as men of science."

Before considering what qualifications an examiner ought to possess, and the proper educational function of examinations, it may not be altogether inappropriate to quote some remarks by Dr. L. Wiese, to show what is the opinion of the advanced intelligence in Germany of the system of examinations and competitions which is now carried out in England on so extensive and ever-increasing a scale; China is still ahead of us in this respect; but examinations and competitions in that land have produced, it has been stated, a general and incurable senility, but then they have been in operation there for a much longer time than in the United Kingdom; and therefore the effects, which it takes time to reveal, are not yet with us in sight.

"Examinations and prizes are looked upon in England as the most effective means of producing the desired effect; other means are either unknown, or are not attempted. The administrations of German schools are more concerned about securing the right way to the goal, and about seeing it rightly

leaving examination who have privately prepared themselves, is comparatively very small. In England attention is almost exclusively directed to the demonstrable final result. From time to time something like an alarum-bell sounds throughout the country: Come and be examined! And they come, boys and girls, young and old, having crammed into themselves as much knowledge as they could. How they have acquired what they know is never asked, nor are they shown what is the best method; and yet what work could after all be more worthy of a university than to point this out? Results! results! this is characteristic of England, and best explains the present high value set upon examinations in schools and universities.

"It is strange that Englishmen who attach so much importance to the free development of individual character do not see that this excess of examination is in direct opposition to it.

"Of all the contrasts which the English mode of thinking and acting shows, none has appeared to me so striking and contradictory as the fact that a nation which has so great and sacred an idea of duty makes no use of that idea in the school education of the young; it has rather allowed it to become the custom, and it is *an evil custom*, to regard the prospect of reward and honour as the chief impulse to industry and exertion. Nelson's words to his men before the battle of Trafalgar are well known

and whoever resides in England has plenty of opportunities of observing in the family life and elsewhere in the actions of men the effects of a widespread and deep sense of duty; every child that learns the English Catechism carries from it into life the command everywhere to do its duty. . . . . Even he who is not so rigorous as to condemn in schools every appeal to ambition, will not be able to approve of the manner in which it is fostered in English schools. At all stages of instruction, from the university to the elementary school, rewards and prizes are in England among the chief incentives to industry; even in Sunday-schools, which are sometimes held in churches, incredible as it may seem, this means is thought indispensable. Prizes and medals are given not only for good progress in learning but also for good conduct. As the custom is universal no doubts about it ever arise; it has always been so. . . . .

"About the end of July of the present year (1876), when after the closing of the schools many pupils went home for the holidays, I heard a father greet his son at the railway station with the question: 'How many prizes?' And when the boy said 'Three,' the father's countenance seemed to ask, 'No more?' In Scotland I heard a mother on a similar occasion say: 'What place in the class?' With us in Germany the question

would be: 'Have you been promoted?' or 'Have you a good report?' . . . . You may hear Englishmen say: 'You must pay people if they are to learn anything, otherwise it will not do;' and their argument, the logic of which looks like cynicism, is, 'Do you suppose that barristers occupy themselves with law, or the physician with medicine, from a love of the thing? No! they want to earn money. Why should we demand greater disinterestedness from young men?' "*

Such is the opinion of a distinguished German Educationist of some of the evils examinations are producing in England. As the separation of the two functions, teaching and examining, is increasing in the United Kingdom, a second examining university, the Royal University of Ireland, having been established, and a system of examinations for intermediate schools in Ireland having been also endowed by the State; along with the host of other examining bodies, as those of the Department of Science and Art, the City Guilds' Technical examinations, &c. &c., it may not be unadvisable to learn what the effects are considered to be in a country where the system of making

* "One of the most eminent services which the German Universities—possessed of no national trust-funds wherewith to make annual money-scrambles—are able to render to the German people, consists in setting before them, both in theory and in practice, a high unselfish ideal of scholarly excellence."—Mr. Sedley Taylor, *Open Endowed Competitions at the Universities and their Results.*

teaching subordinate to examinations, which must ever be the case when the two functions are separated, has been longer tried than in our own. I have already stated, at the close of the second Lecture, that examinations in Germany are subordinate to teaching, whereas in France teaching is subordinate to examinations, the two functions being separated. "We are not the educating body," say the French Professors, "the State constructs the machine of education, and it only gives us a handle to turn."* Let us see what Frenchmen themselves think has been the effect of the system in France; I will for this purpose quote from a pamphlet by a distinguished authority on Education.†

"France has completely separated these two functions, and its University forms an excellent study for those who would advocate a State interference with university examinations. I have

* "The French have exaggerated and perfectionated the mechanical element in education; the Minister of Public Instruction can boast that he can tell at any moment what lesson every boy in France is learning; but in so doing they have destroyed the *human* element, and they are beginning to find that it is only men that can make men, and that a system of machinery worked by wires from a centre, however ingeniously it may be constructed, turns out but poor imitations of humanity. How fully the Athenians grasped the truth on which I have just dwelt is seen from their word for attendance on a great man's teaching: it is *συνουσία*. It was the improvement to be got from *his company* which was the first thing they thought of."—H. Latham, *On the Action of Examinations.*

† The Right Hon. Lyon Playfair, M.P., *On Teaching Universities and Examining Boards* (1872).

alluded to the early history of the University of Paris, when its teaching and examining functions were united, and for nearly six hundred years it produced men of intellect and men of action, who made France the wonder and admiration of nations. The provinces of France imitated the University of Paris, and, before the great Revolution, twenty-three universities, each with a separate autonomy, were spread over the kingdom, adding largely to its intellectual productiveness. But these provincial universities were destroyed by the great Revolution. Napoleon I. reconstituted the University of Paris in 1808, by making it the single university for France. He did this with the power of a military despot, and with the professional instincts of a drill-sergeant. The University of France now became the department of State Instruction, and included every kind of education—Primary, Secondary, and Collegiate. The State in France now received, in its highest form, that function which Mr. Lowe (Lord Sherbrooke) has announced to be the highest duty of the State, the dictation of the curriculum and the examination of scholars. It carried on this double function for more than sixty years, and the result has been, in the opinion of the most eminent Frenchmen, that its operation, more than any other cause, has led to the humiliation of France as a nation. Recent events have strengthened the conviction which De

Tocqueville expressed twenty years ago—that there is a continually increasing poverty of eminent men in France. I will cite the evidence only of men of the highest eminence—Members of the Institute, or Professors in the University itself. Their opinions may be taken as answers to the question which forms the title of Pasteur's pamphlet: 'Pourquoi la France n'a pas trouvé d'hommes supérieurs au moment du péril?' That is a grave question for France, and its best sons are trying to answer it; but it is melancholy to see the assaults that they are obliged to make on a University which, in its days of independence, used to be hailed as 'the fountain of knowledge,' 'the tree of life,' and the 'candlestick of the Lord'—terms which were accorded by the enthusiastic admiration of all countries. First, let Pasteur, whose eminence I need not advert to in an academic assembly, answer for himself:—'While Germany was multiplying its Universities, and establishing among them a most salutary emulation; while it was surrounding their masters and doctors with honour and consideration; while it was creating vast laboratories furnished with the best instruments—France, enervated by revolutions, always occupied with sterile aims at a better form of government, gave only a heedless attention to its establishments of higher education.' The unanimity is surprising with which eminent men ascribe

the intellectual paralysis of the nation to *the centralization of administration and examination* by the University of France. Claire Deville says,—'The success of Germany is due to the liberal organization of the German universities. It is Science that has vanquished us.' Dumas, one of the most eminent men in France, formerly a Minister, and for years actively engaged as one of the eight inspectors of Superior Instruction in the University, gives his testimony as follows:—'If the causes of our marasmus appear complex and manifold, they are still reducible to one principle—administrative centralization, which applied to the University has enervated superior instruction.' . . . . He then indicates what is necessary for the restoration of France to her position among nations: 'Restore to our Universities, under the surveillance of the State, when connected with State grants, the independence which they enjoyed before the Revolution. The great men of those times are glorious historical witnesses of the vigour of the studies, and of the discipline effected by the liberty of education enjoyed by our fathers. . . . . I plead for the autonomy and liberty of our Universities.' Quatrefages, General Morin, and others, express themselves in nearly similar terms. Lorain, Professor in the Faculty of Medicine, gives testimony if possible still more emphatic: 'The University of Paris now influences higher

education only through the faculties of Law and Medicine; for though the schools of literature and pure science have still their Professors, they have no longer pupils.' He tells us that a central University, professing to direct everything, really directs nothing, but it trammels all efforts in the provinces: 'Originality in the provinces is destroyed by this unity.' . . . . .

'We demand,' he states, 'the destruction of the University of France, and the creation of separate Universities. That is our programme.' I have hitherto quoted the opinions of men of science, but I might add to them those of a long list of politicians and men of literature, from Talleyrand, Turgot, De Tocqueville, Prévost-Paradol, down to the present day. . . . . And finally, to quote a distinguished clerical opinion, I give the words of Renan:—'The system of examinations and competitions on the great scale is illustrated in China, where it *has produced a general and incurable senility*. In France we have already gone far in the same direction, and that is not one of the least causes of our abasement. The paltry faculties created by the First Empire in no way replace the great and beautiful system of rival Universities, with their separate autonomies—a system which all Europe borrowed from France, and which all countries but France have preserved.' . . . . . You will deem it to be very surprising that the

system which has so much injured France in the past is to benefit England in the future. France has not failed because she was deficient either in institutions, teachers, or pupils. Of all three she is far richer than this country. But they are separate schools, such as Mr. Lowe (Lord Sherbrooke) hopes to see arise by private efforts; they have no university organization, none of the activity of little intellectual republics; nothing to nourish or stimulate the independent growth of intellect throughout the nation. An empire of thirty-eight millions of people had only one University, situated in the capital, and that one subject to the State. It thought that intellect might be fostered by special schools acting as organs to one great nervous centre; but the organs have not fulfilled their functions, and the nervous centre itself has consequently dwindled away."

The public in the United Kingdom are now attaching far more importance to Examinations owing to the MATERIAL REWARDS which are made to depend upon them, than to the far more important question, how their children are taught. The examiner now controls the teacher; if the former is negligent about, or unfit for, his duties, the latter and the taught are the sufferers. Hence it becomes, in this day of examinations, almost more important to test the qualifications of those

who seek the office of examiner, than those who seek the office of teacher ; for the examiner is now the despot in education, and accordingly as he discharges his duties well or ill, so will he aid or injure the work of real instruction. It has therefore been proposed, and not without a show of reason, that the candidates for the office of examiner should be elected by competitive examination ; the examination would, at all events, have this good effect, it would have a tendency to exclude incompetent people from the office. Professor Humphry, in his "Hunterian Oration," observes : "The difficulty of carrying out a rational and really beneficial system of education, as opposed to cram, is an increasing one, and is in the main attributable to two factors, both of which are unavoidable, and which it is, therefore, our business to grapple with and seek to turn to good account. The first is the mass of facts, which accumulates with increasing rapidity in every branch of science, rendering the study of each more laborious, and so dissociating it from others, and reducing the range which any individual can possibly grasp. The second difficulty is that of examinations ; . . . . so to order them that the *maximum of good and the minimum of evil* may result from them is the *great educational problem of our time.*"

Hunter states, in his "Principles of Surgery," "that his object was to fit his pupils to

may require from comparing and reasoning on known principles. Too much attention," he goes on to say, "cannot be paid to facts; yet too many facts crowd the mind without advantage, any further than they lead to principles."* Froude has expressed the same idea in other words; he says, "The knowledge which a man can use is the only real knowledge, the only knowledge which has life and growth in it and converts itself into practical power. The rest hangs like dust about the brain, or dries like rain-drops off the stones."

That examinations as a rule are well conducted, few, I think, connected with teaching will venture to affirm; there is a universal cry, both amongst teachers and taught, in every department of learning, whether it be that of general education, of science, of medicine, &c., against the mode in which they are generally conducted. Those who take only a cursory view of things are apt to suppose that all that an examiner requires is a knowledge of his subject; they have little or no appreciation of the exceeding difficulty of the task of thorough examination. In a former part of this work I have endeavoured to show that mere knowledge alone does not fit a man to be a teacher, still less, in my opinion, does it fit a man

* "These words give the very marrow of sound teaching, and should be graven wide and deep in the walls of every school, and in the heart of every teacher. They have, alas, been too little heeded."—Professor Humphry.

to be an examiner. An examiner requires, in addition to knowledge, many qualifications; some of them we shall endeavour to point out presently. The office ought to be given to no one who has not made education a study, and it will, in the majority of cases, be best discharged by those who have made teaching a profession; by this I do not mean to say that every teacher will make a good examiner; but a teacher is likely to discharge the duties better than one who has only theoretically studied the subject; and the office ought certainly never to be given to those who have not done so, for they cannot seek it for the love of education, but simply for the money, and therefore, independent of their not possessing the requisite qualifications, they will in ninety-nine cases out of one hundred discharge the duties even from their own point of view in the most perfunctory manner, especially when it is not a continuous office, but terminates probably in one or two years.

To be a good examiner one requires to have deep and enlarged views of the examination subject, a mind ingrained with principles, not with mere facts, a mind that soars above the pettiness of putting one's own particular views and theories constantly in the foreground, or making the questions an exhibition of one's own apparent cleverness, and making a knowledge of these peculiarities and excrescences the crucial test, rather than

the generally received and accepted views on the subject. Examiners ought, of course, to be strictly just and impartial by being uniformly stringent or uniformly lenient. And they ought to have sound judgment on all matters relating to education, and they ought to have the faculty of comparison well cultivated. They should also feel a deep sense of the responsibility and national importance of their office, and endeavour to make their examinations as efficient an Educational instrument as possible, by so framing their questions that they test the reasoning capabilities and intelligence of the examinees, rather than, as is too frequently the case, the mere mechanical or portative memory alone.* The former class of questions requires considerable thought for their preparation, and great labour in examining and rightly appraising the answers; for the preparation of the latter the mere glancing over a book suffices, and the answers are far more readily and easily dealt with than the former.†

* "Of the three kinds of questions, which may be called—1, *Preliminary* questions; 2, questions of *instruction*; and 3, questions of *examination*,—the last alone are, by a considerable portion of instructors, commonly employed. And the elementary-books commonly known as 'catechisms,' or 'books in question and answer,' consist, in reality, of questions of this description. But the second kind—what is properly to be called instructive questioning—is employed by all who deserve to be reckoned good teachers."—Archbishop WHATELY.

† "The great evil of examinations, and the more strenuously

Examination papers are not unfrequently of such an unreasonable length that if the examinees knew the questions before they entered the examination-room, it would occupy more than the time allotted to the examination merely to write out the answers; the examiner by this mistaken judgment makes rapid penmanship an acquirement superior to learning and genius. Mr. Todhunter, in his work "The Conflict of Studies," says:—"I should like to see the papers so short that mere rapidity of handwriting could exert no influence, and the candidate would either solve every question, or, by his omission, confess his inability." Mr. Latham, in his work on Examinations, has some excellent observations on this question of time:—"I have observed," he says, "as a constant symptom of young minds growing into fertility and power, that their best thoughts mostly come as after-thoughts. An idea occurs to them at first in a somewhat bare or imperfect form, and when they review their work, some valuable extension, or necessary qualification, or happy illustration, is suggested. We see the same thing in translation—

dency to make facts preponderate greatly over thought. It is a far easier and quicker process to test the student's knowledge of a fact than his capacity and habit of thinking upon and turning the fact to account. Yet, it need not be said, the latter is infinitely of greater importance. Indeed, a fact is of little value, and little likely to be retained by the brain, unless it is graven in, and rendered

the word that is interlined on revision is often that which shows that the writer has caught the point—and after solving a mathematical problem some simpler process may strike the student when he reads over his performance. What the student has said or done in his first draft remains by him without his knowing it, while his attention passes on to other matter. 'Unconscious cerebration' is taking place all the time, and when he recurs to what he has written, he finds that his ideas have grown, and his conceptions have become more exact. This perfecting power marks minds of a high order, and we should be careful to give an opportunity for its display; whereas, if scanty time be allowed for revision, an advantage is given to men of quite a different type—men who never improve upon their first ideas—with whom work 'is done when it is done.' The performances of such may often be better than the first draft of an abler man's writing, but inferior to the revised copy. Of course, candidates should be given to understand how much more important *quality* is than *quantity*, or they may use the extra time in covering more paper." There should be time not merely for answering but also for revision. An examination should not be turned into "A Great Writing Race," as the late Professor De Morgan used to style the examinations at Cambridge. Further, if the time allotted is too short

for answering all the questions even by rapid writing, each of the examined will choose those questions he considers he can best answer, and thus the difficulty of rightly appraising the answers of the different candidates will be greatly increased.*

Then, again, examiners frequently appear not to take into consideration whether their subject is only one of several, or it is the only one the examined have had to prepare, and whether it is an examination of boys or young men ; no difference in the questions set being made in these dissimilar cases, either as regards their difficulty or the extent of knowledge required for answering them properly.

Professor Tait, in an address he delivered not long ago at the University of Edinburgh, stated that examination, or "artificial selection," is, as too often conducted, about the most imperfect of human institutions ; not long ago, he stated, he saw an advertisement to the effect, "History in One Hour. By a Cambridge Coach." How much, he asked, must this author have thought of the ability of the examiners before whom his readers were to appear ?

* I think the plan that has been adopted in the examinations of the Department of Science and Art of attaching a number to each question, to show the examinee the number of marks the examiner will give for a complete answer to each question, is a very great improvement, and one well worthy of being followed.

The Rev. Canon Barry, in his paper on "The Good and Evil of Examination,"* states: "I hold it possible by examination, deliberately and carefully conducted, to test and to estimate in those who are submitted to it, not only formed knowledge on this or that subject, but intelligence, thoughtfulness, and promise of future growth. That this is a difficult task, I admit; but I believe that an examiner, who brings to this difficult task the natural qualifications and the amount of study which it requires, can, in a very great degree, succeed in the attempt, provided that he is allowed sufficient time, and that he makes use of all the various means of examination which are at his command."

The examiners of some examining departments have occasionally to make reports on the state of preparedness those they have examined exhibited, and it is generally one of complaint as to the defective state of the examinees' attainments in their subjects; they themselves not appearing to be cognizant of the fact that their method of examining not only shapes the mode of teaching, but the kind of books that are written on the subjects. For public competitive examinations have broken down the independence of the teacher; he cannot select the subjects he thinks it would be best for the pupil to know in his future career,

* *The Nineteenth Century*, 1878.

for the pupil will only learn what the examiners prescribe; and the teacher, moreover, must adopt that mode of teaching which best suits the kind of questions the examiner gives; for parents and pupils seek not sound education, but successful preparation, and that with the least expenditure of time and brains; "as to excel in examinations is now a profitable art, it may be called a Profession in itself."*

What do examiners aim at in public competitive examinations? Is their object to find out, as Mr. Todhunter asks, the knowledge or ignorance of the candidates? Do they endeavour to give as many marks as possible, or as few? What kind of knowledge do they intend their questions should test? Are they to be tests of the knowledge which is available for use; or are they to be more immediately directed to ascertaining the mental discipline the examinees have undergone in acquiring the knowledge, or will their questions, or a sufficient number of them, admit of being answered by a knowledge that is artificial and

* "It must be confessed that examiners are frequently hampered by the restraints of the regulations under which they act. This is more especially the case with modern schemes and boards of examination; the official programme is sometimes drawn up, and the system administered by men who, however highly distinguished, are themselves practically without any experience in teaching or examining."—*Conflict of Studies and other Essays*, by Mr. TODHUNTER.

spurious, a knowledge that is fabricated for examination purposes, the so-called taught having been simply made receptacles for a short time for a commodity improperly called knowledge or learning, which is to puff out at a given time like steam out of a steam-boiler, and, like it, will not return again to the receptacles from which it issued.

The mental qualifications necessary for being a good observer or experimenter cannot, as we have already pointed out, be tested by written examinations; and the questions given at written examinations of the Inductive Sciences seldom test the examinee's power or capabilities of thinking on the subject examined upon; they are usually questions about facts, concerning which the candidate has had no experience, and therefore the answers he gives to them must be simply what he recollects from what he has read or been told about them; his answers can only be mere memory answers. For he cannot have any thoughts of his own on the subject, yet this is the way that half our mental wealth comes; he has been furnished with no *material* to enable him to reason about them; and the facts that can be discovered only by observation or experiment cannot, as we have seen, be discovered by *pure reason* alone. No intellectual benefit can accrue from a knowledge of that sort, and the acquirements themselves can

be of no service, for it is a knowledge which is not real, it cannot be used, and will therefore either hang like dust about the brain or evaporate like rain-drops off the stones.

It is not difficult, as we shall presently show, to prepare candidates for such a style of examinations in the Inductive Sciences; all that one requires from them is that they should be satisfied with what they are told, not wishing to know the why or the wherefore, and that they have a good mechanical memory. Teachers cannot be blamed for so preparing them, especially if they are paid, not whether their pupils pass or not, but on the "result system;" for the first thing the teacher in both cases, but especially in the latter, has to aim at is to make his pupils win, his teaching must be directed solely to this one object; and in most cases the portative memory will suffice for answering the questions, and sometimes even better than if the subject had been studied practically. When men have to live by preparing candidates for public competitive examinations, they must teach to live; it is not they who are blamable, if any parties are to blame, it is the examiners and examining boards. "It is hardly understood," as Mr. Latham observes, "how thoroughly the educational world is governed by the ordinary economical rules. While employing the motives of gain

to find fault with teachers and pupils for being influenced by these considerations,—they set young men to run a race, and then wonder that they run not to improve their *physique* but simply to win—they make learning a marketable commodity, *and then complain that it is grown for the market.* . . . . All teachers would rather educate than cram. It is painful to them to say, 'You must get off this list of authors and their works by heart. I know it will do you no good, I know that the words Drayton's *Polyolbion* or Evelyn's *Sylva* convey to you no more meaning than if they were the names of Gasteropods, but they will probably be asked for to-morrow.'"

Before giving some illustrations of how questions are given and their effects, and how questions might be given and what their effects would be, I will quote from Dr. Playfair's pamphlet to show his opinion on the effect of questions that can be answered by the exercise of the mere portative memory :—

"Isolated facts and truths acquired by rote or by cram, unconnected and arranged by educational processes, are like useful objects thrown into a lumber press, forgotten when required, or not to hand when remembered. It is clear that you raise the tendency to cram, when you separate the tests of knowledge from the processes of acquiring it.

acquired information, instead of as an evidence of a course of mental training, a good memory will always have an advantage over a thoughtful and trained intellect with less retentive power as to existing knowledge. The Chinese are forced to acknowledge that this is a result of their separate examining systems, and they honestly give large credit to it, as when they force every candidate to write out from memory the whole of the sacred Edict of the Emperor Kanghi. But such a feat of memory is as useless as that of Xerxes, when he learned by heart the names of a hundred thousand soldiers. . . . . It is true that memory is essential in education, as it is in cram, but, in the first case, it is only one of several intellectual faculties which are simultaneously developed ; while, in the second, it is chiefly relied on to obtain a result that, at the best, is only a sham representation of undeveloped faculties. The one method resembles that of the prudent trainer for a boat-race, when he carefully trains all parts of the body, and not merely those which are to be brought into play in the race ; the other is like the system of the unskilful trainer who presses the muscles into over-action and damages the heart for life."

The first example I will select of how questions are frequently given will be one on the detection of arsenic, as it is one that can be made to illus-

memory knowledge, the difference between being able to do or execute a piece of work, and not being able to do it, *but only to put on paper how others have said it should be done.* It is also one that those who are not chemists will be able to understand and appreciate, and perceive the great difference between *real practical*, and *verbal*, knowledge.

The following question we will take to have been given to a class of young men at a written examination, who had learned what little they knew about Chemistry from attending lectures and from books, never having been taught how to experiment themselves. "By what methods would you detect arsenic in any article of food, and how would you separate it therefrom ?"

The answers to any questions on the detection of substances must, if answered by those who have had no instruction in practical Chemistry, be given from memory alone, and could have been of no service whatever in training the mind, and as we shall show presently, can be of no value in aiding any one in performing the experiment ; such facts are useless lumber to any one who has not worked practically at the science, and if they have, they do not require to be told in lectures facts of that kind, unless the lecturer has some new and improved process to make known which has not

But the detection of substances, when they are mixed up with organic matter like food, is not, as a rule, an easy matter even for experienced analysts, and in case of poisonous substances like arsenic, the analytical examination is generally undertaken to decide whether some one has been poisoned or not, life or death depending on the result of the analysis. I think no one would venture to affirm that, because a person could produce in writing what he had been told about detecting and separating a poisonous substance in food, he would be fitted to undertake the analysis in poison cases; and if it does not qualify him for that, what purpose does it serve? It can certainly have had no effect in disciplining his mind, for the fact itself, and the ideas in the hearer's mind, can form no basis on which he could reason respecting it. But we will pursue the subject still further, as we shall be able by that means to bring into relief a subject that it is most important all examiners should ever duly weigh and consider. For this purpose we will select two candidates—the one, although he has never made a chemical experiment in his life, can, when examined, put in writing all the methods known for detecting the different substances that have been employed as poisons; the other cannot perform this CHINESE FEAT, but he has himself studied Analytical Chemistry practically as a science; he has not given

more attention to poisons than to other substances which come within the range of a well-devised analytical course; he is practically acquainted with Analytical Chemistry, not by "*rule of thumb*," but as a science. Now, which of these two candidates, if they were the only ones from which a selection could be made, would the educated public say ought to be selected by the Government and other public bodies as analyst in poison cases?

But in place of the first candidate, the one who can only put in writing what others have done, but can do nothing practically himself, we will substitute a rule of thumb chemist; and there are such—one, for instance, who has been taught to examine for poisons mechanically, by being told or shown all that he knows about it, not having learnt analysis as a science. Whether ought public bodies to select such a man, or the one who has studied analysis as a science, although he may never have examined for any poisonous substance in food in his life? To the latter certainly, for it is not necessary for one who has studied Chemistry practically, as a science, to know—not to speak of remembering this or that particular fact, or to have performed this or that particular operation, when it is necessary for him to apply his knowledge to practical use—he is aware whether he is perfectly conversant with the subject or not;

and if he is not, he knows the sources to apply to for perfecting it; and from whatever source he derives this further information, he can, his mind having been properly trained, make it part of his own intelligence. It is not even necessary for him, nor does he attempt, to remember all the minutiæ for performing analytical and other operations which he has seldom to execute. He refreshes his memory, when it is needed, by referring to some work on the subject. Examination questions frequently exhibit, on the part of the examiner, an utter disregard of the distinction which ought ever to be made between the knowledge the mind ought to be furnished with, and to be ever ready for use, and that which can at best be only imperfectly remembered, and which would not be applied or utilized without previously consulting some recognized and trustworthy authority. Formerly, for example, questions were frequently given at written examinations in Chemistry, and similar questions are not unfrequently given now, requiring the examinees to write down the atomic weights of many of the elements. Now, no chemist would trust his memory with respect to the exact atomic weights of many of the elements; when he has to employ them in calculations, he refers, before employing them, to a book for the exact weights, save those only he is constantly in the habit of using.

Questions on *applied* Chemistry are frequently

given in examination papers; the examination being intended to test the candidates' knowledge of the elements of Chemistry only; and this is not unfrequently done when the examination is confined to boys; I think it would be just as rational to ask candidates in Arithmetic who were supposed only to have advanced as far as division, questions on book-keeping.

I will now give some examples of how candidates can be, and are, prepared to pass written examinations in the Inductive Sciences when the questions given do not test, or only feebly, the examinees' capabilities of reasoning on the subject examined upon. They will be selections from my own experience, and from what others of undoubted authority have told me. That candidate is best fitted for the system, who has not got an inquiring mind, who is content to receive whatever he is told without desiring to know anything further on the subject; and such a one has generally a better, or can be trained to have a better, carrying (mechanical) memory, than one who desires to know the reason for what he is told, owing presumably to the cause, that just as the other senses of a person who is deprived of one, become more acute from being more exercised than they would otherwise have been, so when the reasoning faculties can be put, as it were to sleep, the mechanical memory can perform more duty by becoming more efficient.

(1.) A good many years ago a friend called upon me to ask me, as a friend, to prepare him for a voluntary examination in Chemistry at the London Medical School he was studying at, as a silver medal was to be given to the student who got the greatest number of marks. I found, on inquiry, that the examination was to take place in four days from that date, and my friend had been such a negligent student that he could give me no information about the lectures, and that he knew little or nothing of the science, all that he could really tell me was that twelve questions would be given. If I was to assist him, I saw there was only one way to do it, viz., by cramming him; I therefore told him I would visit him the night before the examination, and in the mean time I would prepare and write out twelve questions I thought the examiner might probably give, with the answers, and that he must commit them perfectly to memory; this was done, and I hit upon eleven out of the twelve questions the examiner gave, as a consequence my friend passed the best; but owing to an informality, which I need not detail, the examination had to be gone over again; my friend again beseeched me to prepare him for the next contest, I did, and adopted my previous plan; I was again fortunate to hit upon eleven out of the twelve questions given; the result was my

I have related this example for several reasons. I had very little experience as a teacher at that time; but it made me ever after pay some attention to any examination papers that came in my way. I have only once since then prepared any one for an examination; and on this latter occasion I did it also out of pure friendship. I pursued the same plan as before, and was equally successful; but on this latter occasion I had an opportunity of perusing a student's notes of the lectures, and the examiners' previous examination papers on the subject; and the student's knowledge was good in other departments of the science; but the prize was much more considerable than a silver medal.

There was a good deal said about a year ago as to whether or not a gentleman had got hold of the examination papers of the Department of Science and Art a day or so before the examination. From what I know of the way candidates are prepared for the elementary stage, and successfully; the coming examination papers are not required when the teacher has access to the past papers of the examiner, which is always the case; and he receives additional assistance, if some particular text-book is a *favourite* with the examiner. And if I may compare small things with great ones, I should be inclined to suppose that it would not be absolutely impossible for a Routh or a Wren to be amongst the Teachers who prepare for the Science

Examinations of the Department of Science and Art. I will presently give one or two *instances in* support of what I have stated.

(2.) A few years ago a gentleman came to study practical Chemistry with me; but he could only continue the study at that time for a very short period, as he was preparing to take his medical degree at the Royal College of Surgeons Ireland; but he told me on leaving he would return, after taking his degree, and prior to going in for some medical examination in London. A short time after he had taken his degree I met him, and he said he was not coming back, as the gentleman who was preparing him in Materia Medica, had told him, that the Chemistry I taught might be a very good kind of Chemistry, but it was not the kind he wanted for the London examination; he had selected for him some pages, in the little work on Chemistry published by Messrs. Chambers, to commit to memory, which he was engaged upon when I met him; his adviser told him that was the sort of Chemistry he wanted; and it appeared he was right, for the gentleman was successful at the examination.

I knew several cases where young boys were prepared for the Chemical Examination of the Intermediate Schools Examination Ireland, by simply committing to memory selected pages in Dr.

"(3.) A few years ago one of the Department of Science and Art Inspectors, in the course of a conversation with me, expressed a very unfavourable opinion as to the benefit to be derived from the Science teaching as it was conducted in these schools; he instanced one, a National School, as an example: this school had been very successful in obtaining medals; he told me the plan the teacher followed was to secure copies of the examination papers which had been given on the Science subjects he taught, and he appended answers to them which his pupils had to commit to memory, and at set times he used to read out some of the questions, and the pupils had to repeat from memory the answers. A gentleman, who was for a short time one of the Assistant-Examiners in Chemistry for the Department of Science and Art, told me that even the best of the papers which came under his notice were all evidently derived from a system of cram, for if a piece of apparatus, say a retort, had to be sketched, it would be sketched as it hung from a wall, not its position when in use. But even this is now reduced to a system of cram, as will be shown in the next paragraph.

(4.) A plan I know to be followed in the elementary stage for Chemistry is to extract the *examination knowledge* from the text-book the examiner more particularly adopts, and boil it

sheet of letter-paper; and this *extract of examination knowledge* the pupils have to commit to memory; there is also sketched on the sheet of letter-paper pieces of apparatus, and in the position they are when in use. And the chemical equations that are likely to be asked are committed to memory, although the pupils know little or nothing of the language as a language. This committing to memory of equations sometimes leads to laughable mistakes, owing to the memory proving treacherous. One example was recently given in a scientific publication;* it is thus recorded:—A student, in working through one of the Science and Art Examination papers in Chemistry, came to the question, "How would you prepare quicksilver?" "By heating nitrate of silver with quicklime," he answered, and gave the following equation to describe the re-action:—

$\underline{2NO_2AgO}$	+	CaO	=	N_2O_4CaO''	+	Ag_2
Nitrate of Silver	+	Quick-lime	=	Nitrate of Lime	+	Quick-silver

The writer of the notice observes that "the lecture notes of this youth must have got rather mixed up in his memory." It is an instance which fully reveals to those conversant with the Science, how utterly worthless was this party's knowledge of it. He was a mere automaton who

had been wound up—"ground up" is the technical term—for the particular occasion.

Written examinations, however perfectly the questions may be framed, cannot be made efficient and practical tests for any of the Inductive Sciences, whether observational or experimental; but as long as they are employed as tests, they ought to be able to single out those who can work, as far as that can be tested on paper, and who have thoughts of their own, and can reason on the principles and facts contained in the examination paper, from those who have learned the Science by cram, that is, by the aid of the mechanical and not the assimilative memory. "The Chemical Problems," as they are called, which I was the first to frame and introduce,* are efficient tests as far as they extend, for the examiner can ascertain by their use whether the examinee can produce on paper what he ought to know; but they have been, in my opinion, unduly used in examinations; one of the reasons being, I think, that the examiner can quickly ascertain whether such questions have been answered correctly. But there are other questions which might be given, which would test as efficiently whether the examinee had been trained to reason and think in learning the science; and although not one of the examinees might be able to answer

some of the questions completely, the answers given would nevertheless distinguish the thoughtful student from the one who had not been taught to think. Some such questions I gave in the last edition of my "Qualitative Analysis" and in my "First Step." I will give a few examples :—

(5.) Knowing that N_2O is produced by subjecting dry NH_4NO_3 to heat, what gas would you infer would be produced by subjecting NH_4NO_2 to heat ?

If this or the following examples were used as *stock* questions, students could be prepared to answer them like any other questions by the mere mechanical memory. I give them only as specimens of a class of questions which could be devised and be entirely free from the character of mere puzzles, which ought never to be given, and which, when first presented, would require the exercise of the thinking powers to answer.

(6.) From your knowledge of Berthollet's laws, what would you infer would be the result of adding a solution of BaH_2O_2 to an aqueous solution of a magnesic salt ?

In the answering of this question, it would be seen, from the magnesic salt selected by the examinee, whether he knew anything about the solubility and insolubility of substances. It would test his knowledge of a still more important subject, if possible ; it would be seen what he knew

about one of the most frequent influences of chemical change.

(7.) In instructing my students in the drawing out of equations, when teaching them the language of the science, I used to show them, by appropriate examples, that the simplest equation was not always the correct one, and I think that questions of this kind might be introduced with success into examinations; the examinees could not be prepared by cram to answer them, and their answers would show how they had been taught. As an example of this class of questions, I will take the conversion of ferrous hydrate into potassic ferrate when suspended in a solution of potassic hydrate, and chlorine passed in; and the question might be put thus: Would the following equation represent correctly the formation of potassic ferrate from ferrous hydrate when the latter was suspended in a solution of potassic hydrate, and chlorine afterwards passed into the solution:—

$$FeH_2O_2 + 2KHO + 2Cl_2 = K_2FeO_4 + 4HCl.$$

What objections, it might be asked, can be urged against the equation, as describing the formation of potassic ferrate in this way?

(8.) I fuse in a furnace two parts of chrome iron (FeO,Cr_2O_3) mixed with one part of potassic nitrate; I treat the fused mass with water, and

add H_2SO_4 or HNO_3 until the solution is acid to test-paper; I then evaporate the solution to the crystallizing point, and allow time for the crystallization. State what substances are formed in the fusion, what substances are dissolved and what are not dissolved by the water, what alteration the added acid effects, and what substance crystallizes out.

For the correct answering of this question a much wider range of chemical knowledge is required, than for the correct answering of five and six; but even if the question were not answered completely, or even only an attempt were made, it would be readily seen what were the examinee's reasoning capabilities as regards the science. Even the mistakes would be valuable indications of whether his was real or sham knowledge.

(9.) Select the substances out of this list which could exist together in an aqueous solution, without any precipitation taking place:—Al_23SO_4, $CuSO_4$, KNO_3, $ZnSO_4$, NaCl, $Pb(NO_3)_2$, Fe_2Cl_6, $(NH_4)_2CO_3$, $BaCl_2$, K_2S, $Ca(NO_3)_2$, NH_4Cl, $KClO_3$.

It would be desirable to ascertain the extent of the requisite knowledge any student had for answering this question; but it would be especially desirable to test the knowledge of those who intended entering the medical profession; it would prevent them from limiting their knowledge

on this important subject to them to what the Pharmacopœia tells them.

Conservatism will, I expect, be opposed to all reformation in the teaching of, and examining in, the Inductive Sciences; the old routine must continue to be followed; any changes to be allowed must be of the mildest sort; no such radical changes as the substitution of real and thorough examination in the field and laboratory for written examinations could for one moment be entertained. If, from whatever cause, no more thorough practical examination can be introduced than the one at present adopted by some examining boards—which consists of an analytical examination, the examination being limited to two acids and two bases—I would propose, in order to prevent students from being prepared for that examination in a mechanical way, that the written examination also given should contain one or two questions like the following and previous one (9), for such questions would show whether the examiner had received that practical education in the science the examination intends he should have received.

(10.) There is present in solution in HCl, Fe_2Cl_6, $CuCl_2$, $CoCl_2$, and H_3AsO_4. I neutralize the solution with Na_2CO_3. I then add Sodic Acetate in excess, and boil for some time, and afterwards filter. The filtrate I acidulate with HCl,

and then pass H_2S through it to excess, and again filter. I boil the filtrate to expel the excess of H_2S, and then pass Cl through it to excess, and then diffuse $CaCO_3$ through the liquid and allow it to stand for several hours. I afterwards add to the filtrate lime-water. What changes take place on boiling the solution after the addition of the Alkaline Acetate? What is precipitated by the H_2S? What change does the Cl effect, and what is precipitated by the $CaCO_3$ and lime-water?

In the few remaining remarks we shall make upon examinations, it may not be undesirable to point out the difference between collegiate and public competitive examinations; the former class of examinations should ever be in entire unison with the systematic course of instruction adopted in teaching the subject; being like teaching one of the instruments of education, but *subordinate* to it; the teacher and not the examiner prescribing the course of instruction. Students who have to pass these *educational* examinations ought to follow the excellent advice the late Mr. Carlyle gave, when Lord Rector, to the students of the University of Edinburgh:—"By diligence I mean, among other things—and very chiefly—honesty in all your inquiries. Pursue your studies in the way your conscience calls honest. More and more endeavour to do that. Keep, I mean to say, an

accurate separation of what you have really come to know in your own minds, and what is still unknown. Be careful not to stamp a thing as known when you do not yet know it. Count a thing known only when it is stamped on your mind, so that you may survey it on all sides with intelligence. There is such a thing as a man endeavouring to persuade himself, and endeavouring to persuade others, that he knows about things when he does not know more than the outside skin of them, and he goes flourishing about with them. There is also a process called *cramming* in some universities —that is getting up such points of things as the examiner is likely to put questions about. Avoid all that; it is entirely unworthy of an honourable habit. Gradually see what kind of work you can do, for it is the first of all problems for a man to find out what kind of work he is to do in this universe. In fact, morality as regards study is, as in all other things, the primary consideration, and overrides all others. A dishonest man cannot do anything real. . . . . He does nothing but darken counsel by the words he utters." It would greatly assist a student in being honest, if he saw the same excellent quality always displayed by his teachers; that he found, for example, that they were properly qualified by knowledge and ability to teach the subject they have undertaken to

their office faithfully and conscientiously, not leaving to assistants or others to discharge the more laborious and onerous portions.

Public competitive examinations reverse the position of the teacher and examiner; the latter not only prescribes the course of instruction, but also, by the questions he gives, the method of teaching, and in some cases the particular book or books to be employed; opinions at variance with those expressed in these books, although they may be more generally received, and be the results of more recent researches, are regarded as untrue, and consequently may, if enunciated by the examinee, be a serious obstacle to his passing. This arises in some cases from the examiner not taking the trouble to make himself acquainted with the more recent investigations in science. Those who prepare candidates for one of the public examining boards, which has more than one set of examiners, have to ascertain which set of examiners their pupils will have to appear before, as they must vary their preparation accordingly, each set of examiners employing a different set of text-books, and from the opinions expressed in the particular books each set of examiners adopts, the examinee must not stray if he wishes to be successful.

"We cannot by our examinations *create* learning or genius; it is uncertain whether we can infallibly

discover them ; what we detect is simply the examination-passing-power of the candidates." The same authority, Mr. Todhunter, says, "I cannot, however, dismiss the subject (competitive examinations) without adverting to the undue importance which is attached to competitive examinations. For mere boyish proficiency in Classics, that is, speaking generally, for merit which consists largely in having been sent when young to a good school, a fellowship of three or four hundred pounds a year is sometimes awarded. The prize seems to me too great to be made to depend on such a precarious method of appreciating claims as even the best examination furnishes. The large rewards thus held out for attainments in certain studies, estimated in a certain way, tend to make our students regard too much the immediate market-value of their knowledge, and to neglect any pursuit which does not promise an early pecuniary return. Hence, we suffer under a disheartening want of faith in all but the mercenary inducements to mental exertion. When any branch of literature or science seems to be inadequately cultivated at the University, and some enthusiasts try to produce an interest in the neglected subject, it is never by the ordinary means of *able teaching* that we propose to afford the required stimulus and encouragement : the universal remedy is to *put the subject into the examinations*."

It is admitted by all Educationists that examinations should not be commenced at too early an age, and it is equally undesirable to continue them beyond the period of youth or early manhood. For the preparing for examinations keeps the mind too much in the receptive state, it is for ever imbibing the opinions of others, not forming any of its own; it is kept by them in the learning stage, when it ought to be in the reasoning stage, and the still higher one of original thought. And "the spirit with which a man works, whose object is display in an examination, is different from that of a man who is engaged in doing good conscientious work, from devotion to a study of his own choosing." And during the examination period, they should not be too frequent; they keep the mind in a state of unrest and excitement, which is not conducive to real mental progress; as the Rev. Canon Barry very happily remarks, "It will not do to be always plucking up the young plant of knowledge to see how it grows." I believe that Sir Joseph Whitworth would more certainly attain the object he has had in view in endowing so munificently the Whitworth Scholarships, for educating those who obtain them in the scientific, as well as the practical, branch of the profession they have adopted, that of Mechanical Engineering, if they were not, after they have attained the scholarship, so

ledge within them is growing; I would strongly recommend Sir Joseph to follow out more closely the old Universities in this respect. If the young men, who have obtained these scholarships, continue to pursue their Scientific Studies at Colleges in the United Kingdom; let the examinations of these colleges or the certificates of the Professors suffice, do not compel them to undergo extra examinations; and let them have free latitude to pursue their studies on the Continent, if they believe they would benefit by so doing.

Examinations have been overdone in every respect, both as regards keeping the examined too long in the state of pupilage—occurring too frequently—and applied to subjects which are utterly unfit to be tested by means of written examinations. I will quote from a leading article in the *Daily Telegraph* in June, 1874, an amusing illustration of the unfitness of some subjects to be so tested:—

"The new National Training School of Cookery at South Kensington, over which Lady Barker and Mr. Buckmaster preside, appears to have taken to examining its pupils almost as naturally as a duck takes to the water. A paper of twenty-five questions, in which a possible total of 1,000 marks can be reached, lies before us. . . . . 'How would you grill a pound of rump-steak?' asks the twelfth question. 'How would you prevent it

from getting dried up? What time would it take to cook?' and against the interrogatory is put in the margin '(60 marks).' Then comes, 'How would you prepare a dish of mutton cutlets? Describe the whole process (45 marks).' Or again, 'How would you make—what is called—melted butter? (25 marks).' Or yet once again, 'How would you prepare a cup of bright, clear, and fine-flavoured coffee? Which of the various kinds of berry should you select, and what quantity of ground coffee would you allow for each cup? (25 marks).' Twenty-five marks only for each of these! Mr. Buckmaster and Lady Barker should know that the *artiste* who can make melted butter, or who can prepare a cup of bright, clear, and fine-flavoured coffee, is not to be appraised by any system of examination papers and marks, or to be bound by any pedantic rules requiring her to 'write on one side of the paper only,' and affix her name legibly to each sheet. Rather the school that can turn out a constant supply of such treasures deserves to be at once richly endowed.

"We believe that Mr. Buckmaster lectures upon the preparation of sauces of all kinds, from Périgueux to Béchamel, from Mirepoix to velouté, and from ravigotte to espagnole. But the cook who can prepare 'what is called melted butter' as it ought

of flour which stands between failure and success . . . . such a woman commands the whole art and mystery of sauces. . . . . Let Mr. Buckmaster only stick to his melted butter and the sauces will take care of themselves. . . . . The making of melted butter is like fresco painting or etching on steel; you cannot correct your mistakes as you go on, but each stroke stands as it is given for better or for worse. 'The coffee question,' if we may so call it, is equally judicious. To make good coffee —as bright and as clear as a glass of madeira— requires skill in the choice of the berry, skill in roasting it, skill in grinding it, and yet greater skill in extracting from the duly ground *matériel* the delicate preparation. . . . . So much for Mr. Buckmaster's examination-paper, of which all that can be said is that a 'professor' able, not only to answer the questions propounded therein upon one side of her paper in a legible hand, but—to use the apt phrase of Mr. Wackford Squeers—able also to GO AND DO IT, would well deserve a high salary. The South Kensington School must, however, beware, above all things, of COOKING UPON PAPER."

Written examinations are as untrustworthy as regards Agriculture, whether they are questions relating to the practical operations of, or to the applications of science to, Agriculture, as they are with respect to Cookery. One hears those who

about "Agricultural Chemistry" as if every school-boy ought to know it, and that Agricultural Chemistry was different from any other kind of Chemistry. Chemistry applied to Agriculture is truly different to the same science applied to most other industries, inasmuch as it requires a more comprehensive general knowledge of the science to apply it with success to Agriculture than to most other industries.

To illustrate what I have stated, I will take the question of soils. We can learn, by the aid of chemical analysis, whether a soil contains all the substances required by plants; but this, hitherto, is all the aid which chemistry has afforded us as regards soils. For if the analyzed soil contains all the essential substances, the analysis conveys to us no information as regards the productive power of that soil. If it should prove fertile, we cannot, in the majority of cases, learn from the analysis upon what its fertility depends; if, on the other hand, it should prove barren, whether it is its chemical or physical properties which require to be altered in order to render it fruitful. As an instance of this I will direct attention to the analyses of four soils made by the late Dr. Anderson; they were taken from two different fields, on one portion of each of which the clover failed, and on the other part it succeeded. One field was described as clay land, the other as

black land. The results were as follows—No. 1 in both instances being the portion on which the clover failed, No. 2 that on which it succeeded :—

SOILS—MILL HILL.

	No. 1.	No. 2.
Soluble silica . .	0·08	0·02
Peroxide of iron . .	4·45	6·68
Alumina . . .	2·40	3·00
Lime . . .	1·23	1·33
Magnesia . . .	0·45	0·25
Potash . . .	0·20	0·22
Soda . . .	0·07	0·09
Sulphuric acid . .	0·05	0·08
Phosphoric acid . .	0·38	0·07
Carbonic acid . .	0.09	0·34
Chlorine . . .	trace	trace
Organic matter . .	4·12	4·14
Water . . .	2·54	2·52
Insoluble silicates . .	83·90	81·34
	99·96	100·08
Soluble in water . .	0·75	0.73
Of which inorganic .	0·44	0·46
organic .	0·31	0·27
Nitrogen . . .	0·15	0·15
Humic acid . . .	0·42	0·43
Humine . . .	...	0·10

SOILS MARKED "MR. BELL."

	No. 1.	No. 2.
Soluble silica . .	trace	0.334
Peroxide of iron . .	5·605	2·423
Protoxide of iron . .	...	2·752
Alumina . . .	3·911	2·454
Lime . . .	0·849	0·702
Magnesia . . .	0·277	0·234
Potash . . .	0·550	0·533

	No. 1.	No. 2.
Soda	trace	0·128
Sulphuric acid . .	0·096	0·154
Phosphoric acid . .	0·213	0·255
Carbonic acid . .	0·179	trace
Organic matter . .	4·275	3·411
Water . . .	3·252	3·250
Insoluble silicates . .	81·012	83·222
	100.219	99·852
Soluble in Water . .	1·337	1·203
Of which inorganic .	0·472	0·587
organic .	0·865	0·666
Nitrogen . . .	0·209	0·209

We see that the necessary inorganic substances were present in each of the four soils, and they did not differ in quantity, in each pair, more than would be the case in two portions of soil from different parts of any field. The only difference of any magnitude, as Dr. Anderson remarked, was between the amounts of phosphoric acid in Mill Hill, No. 1 and No. 2, in the former of which it was more than five times as abundant as the latter; but no inference can be drawn from this difference, as the amount was greatest where the clover failed. In both the soils in which the clover succeeded, sulphuric acid existed in considerably larger proportions than in those where it failed. The amount of sulphate of lime (gypsum) in an acre of each of these soils, supposing them all to be six inches deep, would be as follows:—Mill Hill, No. 1; 17 cwt.; No. 2, 27 cwt.; Mr Bell,

No. 1, 32 cwt., and No. 2, 51 cwt. of the dry substance. Here the difference is sufficiently well marked; but we cannot attribute the fertility of the soil No. 2 to this excess, because Mill Hill, No. 2, on which the clover succeeded, contained less sulphuric acid than Mr. Bell, No. 1, on which it failed. Neither can we attribute the fertility of the one class, and the barrenness of the other, to a difference in the quantity of nitrogen and the other organic constituents, for in this respect also the identity is thoroughly complete. We are, therefore, unable to explain why the clover grew upon the No. 2 soils, and why it would not grow on soils No. 1. Had these soils been analyzed, therefore, before a trial had been made with the clover, no one would have been able to predict that it would grow on No. 2 and fail on No. 1.

In investigating the sugar manufacture in the West Indies some years ago; in going over different sugar estates in Demerara, my attention was directed to a particular circumstance on one estate, showing the influence of the soil on the quality of the sugar produced. White sugar was made in the way they manufactured it, from the juice of the canes grown on one part of the estate, and could not be made from the canes grown on another part of the estate.

The knowledge of agriculture or of the science applied to agriculture cannot be tested by written

examinations; questions like the one I gave in the arithmetical problems I have already alluded to may be answered; the question is this—

An average crop of oats removes from an acre of land 198·9 lbs. of inorganic matter; a crop of barley removes from the same extent of land 213·3 lbs. of inorganic matter. In the 198·9 lbs. of inorganic matter removed by the oats, there are 23·3 lbs. of phosphoric acid, 36·5 lbs. of potash, and 3·8 lbs. of potassic chloride; in the 213·3 lbs. removed by the barley there are 24·3 lbs. of phosphoric acid, and 38·3 lbs. of potash. If the farmer desired to restore his field to its original fertility, what weight of nitrate of potash, chloride of potassium or sulphate of potash, and what amount of bone earth would he have to employ in order to give back the potash and phosphoric acid which had been removed by the oats, and what amount would he likewise have to employ in order to restore fertility after the barley crop?

But I should like to see the answers, not of students, but of the wisest, most learned, and skilled in agricultural science to the following question, which was recently given at an examination of the Department of Science in the second stage:—Does the chemical analysis of a soil always indicate to a farmer what plant-food it contains? Point out the precautions which are necessary to make the analysis of a soil a safe and trustworthy guide.

LECTURE VIII.

On the Teaching of the Higher Branches of Chemical Science—Objections considered—The Reforms urgently required—The Advantages of Continental over English Scientific Schools—The Methods to be Pursued in Teaching the Highest Branches of the Science—How Books on the Highest Branches of the Science ought to be written—What the Student's Aim ought to be—The Mental Qualifications the Student of Experimental Science ought to Possess, Illustrated—How Discoveries are made—Kepler and Faraday's Account of Failures from Erroneous Speculation—Evening Colleges of Science—How they ought to be Conducted and what they could Effect—The Cost of Laboratories.

In the Fifth and Sixth Lectures I have described a plan of instruction which ought, I think, to be followed in teaching the lower and more elementary branches of Chemical Science, and which is capable of being adopted and as fully carried out, as any of the more usual branches of learning, in schools of general education, as well as in Primary Science schools whether day or evening. The subject of the present Lecture will be devoted to the consideration of the methods of teaching the highest branches of the Science, and the next Lecture to the teaching of Applied Science, which can only be carried on properly and successfully in the highest schools, or colleges, of Science.

The remarks on the teaching in these higher Scientific Institutions will embrace the teaching of the highest branches of the study to evening, as well as day students; as my scheme of Scientific Education comprises Evening Colleges, as well as Evening Primary Schools, of Science; and I shall be able to show by facts that evening students can successfully prosecute original inquiry and research.

I apprehend it will be expressed by many, before making themselves acquainted with my entire scheme of scientific education, that the restriction of the teaching in Colleges of Science to the highest branches of the science, although correct in principle, is incapable of being carried out in practice; and many may instance medical schools as one example of the impossibility of its adoption at least at present.* I have not overlooked the difficulties that have to be met and encountered;

* Not a few medical men connected with medical schools believe that it would be an advantage, if students, previous to coming to the medical schools, were required to obtain the necessary knowledge of chemistry and botany they are required to know, so that the teaching in these schools might be confined to purely medical subjects. I think that if the Governors of these schools required of those entering them such a knowledge of Chemistry as I have shown in the Sixth Lecture can be acquired in schools of general education, the teacher of Chemistry in medical schools would then, instead of as at present teaching the merest elements of the science, be able to teach those higher branches of the science which every medical man ought to be made acquainted with, but which he cannot teach, at least with any success, at the present time.

but they are far from being insurmountable. I hope to prove in my Tenth Lecture that if the Government would expend, say one-half the money they are now expending, on a sound and rational system of teaching the lower and more elementary branches of the Inductive Sciences, such as I have developed with regard to Chemistry, instead of the present crude and inefficient scheme, the reformation would be so healthy and vigorous, that it would be immediately followed in schools of general education and in others over which the Government have no control. And if the instruction in the lower branches were made what it ought to be, the improvement in, and extension of, the teaching of the higher branches would necessarily follow. That improvement is required, and that it ought speedily to be introduced, if we are to keep abreast with other nations in manufacturing and agricultural industries, has been shown in the First Lecture, and is strikingly apparent to all who have given the slightest attention to the question of Industrial Education. Our manufacturers have been taught, whether rightly or wrongly, by scientific men, that Continental scientific schools, especially the German ones, and the students from those schools, are superior to our own ; hence they frequently engage German chemists, for example, in preference to their own countrymen ; and can

the head of one of the largest chemical schools in the United Kingdom in advertising for an Assistant, made it an indispensable qualification that he must have studied two years or more in one of the German Chemical Schools.

The advantages Continental Science Schools possess over our own do not arise, as we have shown in the First Lecture, from better money endowments; neither do they, as we have shown, arise from the students being gifted with better intellectual fibre; and it may be said that we follow much the same plans of teaching as are followed abroad. What, then, is the difference owing to? There are several causes, which I will briefly name. 1. Professors, in our scientific schools, are sometimes Pluralists; hence their other duties have, and must have, a tendency to cause them to neglect their students by handing them over in a great measure to Assistants. 2. Owing to the few public appointments open to scientific men, PLURALISM, by reducing the number, tends to discourage men of intellect devoting themselves to the study of science as a profession; in addition to this as our appointments are freely thrown open to foreigners, science is, as a profession, a most precarious one, especially on the first entrance of the student on public life. 3. Another evil of the present time, in my opinion, is the little attention Professors give to practical

lecturing; yet if we are to look to science to improve our industries; it must for that purpose, if for no other, be learned practically in the laboratory; it is only by long-continued work at the laboratory table that the student can be properly educated for the position of a director or manager of INDUSTRIES. That this retrograde change, that of placing higher value on theoretical, than on practical, instruction, is taking place, I need only refer as an example to the way the appointment Dr. Percy held as Professor of Metallurgy in the Royal School of Mines has been filled up. The present *Professor* of Metallurgy gives lectures only; the *teacher* of the most important, because the practical, part of the subject, laboratory teaching, is placed in an inferior position; therefore those who had the giving of the appointment clearly attached more value to theoretical than to practical teaching. 4. Owing to the greater cost of living, the greater cost of education, and other causes, young men in these countries cannot afford to continue as long at college as they can on the Continent; they having to enter upon public life earlier. It is, therefore, of more pressing importance with us, than it is on the Continent, to adopt the most perfect systems of instruction; and thus conform our educational systems, as far as possible, to the different and more adverse circumstances under which our young men are placed. 5. The Government Science Schools,

as at present carried on, have a tendency to train students up in the particular views of one class of scientific men only; this imperfection will be more fully dwelt upon in the Tenth Lecture. 6. I also think that the giving of lectures, year after year, on the most elementary facts and principles of a science, by those who ought to be occupied in teaching its highest branches, has a benumbing and deteriorating influence on the mind, especially on the minds of those who have no strong and ardent love for the duties of a teacher, no great sympathy for their students, and that it tends to produce indifference and lukewarmness in teaching. This, of course, would have the same effect on the teaching in Continental Schools as in our own, but there there are counteracting agencies at work.

Since the time Liebig made Giessen famous as a Chemical School for students, the German Universities have been rightly regarded as excellent schools for the student of the Inductive Sciences; but to suppose, as some do, that every German educational institution of whatever kind is better in this respect than our own, is an erroneous supposition. I have had to teach, as I have already stated, those who had attended courses of lectures on Chemistry in their schools of general education, and I certainly did not find that they had been better taught than English students who had attended similar courses of instruction in these

countries. An Austrian gentleman, who had attended, at a Polytechnic School in his own country, a course of lectures on Chemistry, came to Queenwood College, Hampshire, to study the science and practice of agriculture; I had the pleasure of teaching him Chemistry. On leaving Queenwood he went to a large Agricultural College in Germany; he sent me, in a letter, the following description of the laboratory of that Institution: "With regard to Chemical Analysis it is quite pitiable; the analysis is confined to that of soils; the greater part of the students merely have the tedious work of filtering and weighing; at times they observe the Professor pouring some yellow or colourless liquid into their beakers; they notice a strong disagreeable smell, or that it volatilizes when in contact with the atmosphere; but that is all they know about their re-agents; besides, there is such dirt and disorder, that one invariably finds a crust of dirt on one's filtrate, or what is more frequently the case, a beaker or two upset. I am so disgusted with it, that I have resolved to go there no more. I need not say how often I have thought of your beautifully-regulated laboratory,* and how I doubly appreciate everything now."

English chemical philosophers, as Davy, Graham, Andrews, &c., have been in no way

inferior to Continental ones; it is evident, therefore, that our Schools of Science in the United Kingdom do not want the intellectual fibre to make them equal to those in Germany and France. The first and most important reform required by us is thorough practical instruction in the elementary branches of one or more of the inductive sciences, taught by those competent to teach, in schools of general education, and in Primary Science Schools. Our Colleges of Science, whether pure or applied, after this great educational reformation had taken place, *would soon equal those on the Continent*, it under proper direction and management.

In teaching the highest branches of pure science in conformity with the scheme I have proposed, we should have to make use of the three methods of teaching—namely, oral instruction, books, and practical instruction in the laboratory. It is necessary, therefore, to explain in what way they should be carried out.

The Lectures should consist of catechetical lectures on the principles and leading facts of organic chemistry, and professorial Lectures in the form of *description* and *annotation* on the most important discoveries of the day, and they should not be restricted to any one department of the science, but embrace all the departments. As mere routine could have no place in this kind of

those who continually kept themselves thoroughly acquainted with all that was taking place in their science; no number of lectures could or ought to be assigned for the Professor to give; he would have to be left as free in the number he gave, as in the subjects he selected.

The books to be studied by the students should not be of the usual dry compendium or manual type; they should be books written by scientific men *for scientific men*; they should be so constructed that instead of making the student accept the facts and principles on the *ipse dixit* of the book, the different views entertained by men of science on disputed and unsettled portions of the science should be collated, and the several arguments by which the different views were maintained should be given so as to teach him to form his own opinion on disputed and unsettled points, rather than be merely content with the opinions of others. The description of the discovery and formation of substances, for example, should be narrated as closely as possible in the way the investigation was made; what views, for instance, led to the undertaking of the investigation; how it was carried on; what difficulties were encountered, and how they were overcome; how the composition and rational formulæ of the substances produced were determined and proved, and what, if any, objections and arguments could

be urged against the interpretation given of the discoveries. Books of this class would be the best adapted for developing original thought by teaching the student to swim without corks, and would best fit him for reading original memoirs on the science. This aim I had in view in writing my work, "The Students' Guide in the higher branches of Chemistry." As no work had previously been written in this way, nor since, it was with no little pleasure that I read in the *Chemical News* the high eulogium so distinguished a judge as the late Professor Graham had passed upon it at a public meeting of chemists ; and this was rendered the more gratifying as the book had not sought that distinguished chemical philosopher, as no presentation copy had been sent him, but he had sought the book. But books, even of this class, must only be aids for the studying of original memoirs of the science; it is those, and chiefly those of the highest class, the student must study, for, as has well been stated, "Original research does not come by the light of Nature, except to men of absolute genius; it must be learned by carefully studying the methods of the greatest discoverers and investigators, and seeking to apply them in actual practice."

In passing on to the practical work, we must state what the aim and character of the student of experimental science should be; but we must

precede this by stating that the student must no longer be "*staggering along with our competitive old man of the sea established on his back;*" he must have done with competitive examinations; for if these exist, as has been well stated, there can be neither dignity, freedom, nor freshness in the work either of the professors or the students; if university degrees are to be given to the student they must be given for the original work he has done, and not by examination.*

The aim the student ought to have I will convey by selecting a passage from one of the lectures on "The Plant; a Biography," by the Professor of Botany in the University of Jena, Dr. Schleiden, lectures which he said were free from the "dust of schools." "A brewer's son, of Huntingdon, Oliver Cromwell, raised himself in a few years to be absolute ruler of Great Britain, and, by the power of his mind, gave law to half Europe. Tradition tells of a speech of his, in early youth; 'He goes the furthest who knows not where he wants to come to.' This saying may be thus expressed in less paradoxical language. A man only attains to something great when he, from the beginning, takes the highest object, the unattainable ideal, for his aim. In

* What a stimulus it would give to the cultivation of original research if the University of London and other Universities conferred their degree of Doctor of Science at least only on those who had distinguished themselves by original work.

this manner, we may take Cromwell's maxim as a guide in every science, and we shall find that its power is here in no way belied." It is said of one of the authors, from whose works I have given so many valuable extracts, Dr. Whewell, that when there appeared little chance of his ever studying at Cambridge, he declared he would not only go there, but become Master of Trinity College in that University; which he not only attained to, but so much adorned.

The experimentalist must be thoroughly imbued with *truthfulness*, *candour*, and *courage*; he must possess, besides these, many other qualifications; but for a detail of them I must refer the reader to Professor Jevons's excellent work, "The Principles of Science." I will give his concluding paragraph on the subject: "Summing up, then, it would seem as if the mind of the great discoverer must combine almost contradictory attributes. He must be fertile in theories and hypotheses, and yet full of facts and precise results of experience. He must entertain the feeblest analogies, and the merest guesses at truth, and yet he must hold them as worthless till they are verified in experiment. When there are any grounds of probability he must hold tenaciously to an old opinion, and yet he must be prepared at any moment to relinquish it when a single clearly

sopher," says Faraday,* "should be a man willing to listen to every suggestion, but determined to judge for himself. He should not be biassed by appearances; have no favourite hypothesis; be of no school; and, in doctrine, have no master. He should not be a respecter of persons, but of things. Truth should be his primary object. If to these qualities he added industry, he may, indeed, hope to walk within the *veil* of the TEMPLE OF NATURE."

We have now to consider the third method for teaching the higher branches of the science—namely, practical instruction in the laboratory. On this division of the subject it might be alleged there was little that could be said, as no rules could be laid down which would enable the student to make scientific discoveries; although that is the case, a few remarks may be made, which may at all events be useful, and, therefore, acceptable to students. The student having gone over the course of practical study laid down in the Fifth and Sixth Lectures, will be competent at once to commence the quantitative analysis of complex inorganic substances, gas analysis, organic analysis, and the preparation of inorganic and organic substances. And in the preparation of organic substances there might be combined with the preparation somewhat of a research; for example, the student might go over Liebig's research on food, obtaining, separating,

and purifying the different substances he obtained; this has always appeared to me a model of a research of that class of discoveries which consists in the discovery, extraction and separation of substances, which have been formed by natural processes, and which are present in complicated mixtures; even the way Liebig discovered the presence of the phosphates of different constitution in different kinds of flesh is well worthy of the attention and study of the student.

But the *object* of the student, whether he intends to devote himself to the cultivation of pure science, or to the management and development of chemical industries, or in the application of Chemistry to Agriculture, or to Medicine, must be to enter upon original investigation; this is as important for those who intend to become physicians, or to devote themselves to industrial pursuits, as for those who intend to study science for its own sake; for it is only by research that new inventions can be made, and chemical manufacturing processes, at present employed, improved. "Original Scientific Research aims at the discovery of new truths of Nature, and the elucidation and explanation of natural phenomena, by means of experiments, observation, comparison, and reasoning. It is, in its fullest scope, an almost unlimited subject, because it includes all investigations in the whole of the sciences; and these treat of the entire universe of

and its energies, including mind and its processes."*

We have answered in one way, the question the student may ask, "How are discoveries made?" by noticing some of the qualifications a discoverer ought to possess; but it may be answered in a somewhat different way, or rather put in another light. Although the discovery of a new scientific fact is a new truth brought to light; yet many discoveries are small ones, and many are unimportant: for instance, if a law or principle has been by the discovery of a class of facts established in Chemistry, the discovery of further facts of that class, after the law has been established, becomes unimportant unless they possess some individual intrinsic value. The student must not suppose that every discoverer possesses all the qualifications I have named; but in proportion, as he is deficient in them, in the same proportion will the discoveries he makes be small and unimportant ones. Science begins with *common* observation of facts; they are the materials of science, but as long as they remain insulated and disconnected they do not constitute knowledge; ideas are required to unite them, and it is by the possession of facts and ideas that science is constructed. "When they are separated from each other, the neglect of Facts gives rise to empty speculations, idle subtleties, visionary

* Dr. Gore on "The Art of Scientific Discovery."

inventions, false opinions concerning the laws of phenomena, disregard of the true aspect of Nature; while the want of Ideas leaves the mind overwhelmed, bewildered, and stupefied by particular sensations, with no means of connecting the past with the future, the absent with the present, the example with the rule; open to the impression of all appearances, but capable of appropriating none. Ideas are the *Form*, facts the *Material*, of our structure. Knowledge does not consist in the empty mould, or in the brute mass of matter, but in the rightly-moulded substance." Analysis, for example, is only a means to an end; many might, for instance, have examined the different phosphates, the analysis might have been perfectly accurate, but as long as the conception of their constitution and relation to each other was wanting, they were simply disconnected facts; but Graham, by furnishing the true conception of their composition and constitution, made them important illustrations of a great principle in the science.

The student must expect, when he first enters the domain of original inquiry, that the ideas he forms will often prove erroneous; they will generally be crude and complex, and it will only be by long-continued study that his conceptions will be appropriate, that his guesses about the truth prove happy ones, and that the hypotheses and theories he frames and invents agree with the facts. I

have, in one of the former Lectures, stated that it is to be regretted that so few chemical investigators describe in their investigations the precise conditions under which the new substances they have discovered are produced; this, as I have stated, renders the science more empirical than it would otherwise be. But if they were to add to the description of the conditions what views led to the undertaking of the investigation, the memoirs would be rendered far more valuable studies for the student; he would learn from them that if he obtains very different results in any investigations he may undertake from those he preconceived in setting out on the inquiry, he is not by any means exceptional—it is the lot of all inquirers into the undiscovered truths of Nature; and not unfrequently do investigators find that they have been searching for the unattainable, at least that which they cannot attain. "It is the peculiar character," states Dr. Whewell, "of scientific contests, that what is only an epigram, with regard to other warfare, is a truth in this—they who are defeated are really in the wrong. But they may, nevertheless, be men of great subtilty, sagacity, and genius; and we nourish a very foolish self-complacency when we suppose that we are their superiors. That this is so, is proved by recollecting that many of those, who have made very great discoveries have laboured *under the imperfection of thought which was*

the obstacle to the next step in knowledge. Though Kepler detected with great acuteness the Numerical Laws of the solar system, he laboured in vain to conceive the very simplest of the Laws of Motion by which the paths of the planets are governed. Though Priestley made some important steps in Chemistry, he could not bring his mind to admit the doctrine of a general Principle of Oxidation. . . . . To err in this way is the lot, not only of men in general, but men of great endowments, and very sincere love of truth."

Investigators do not, as we have stated, as a rule, tell us of the erroneous ideas they frequently set out with, in their search after truth; still less do they tell us of their failures; but two physical philosophers, Kepler and Faraday, have left us, especially the former, some account of their failures from erroneous speculation, as well as of their successes, in their inquiries, into the secrets of Nature. "Kepler, who pursued his investigations with a keen and restless activity, was ardent, enthusiastic, and subtle; he was also patient, laborious, and determined; difficulties shrunk at his approach, and obstacles melted before him." He has narrated, with candour and copiousness, how on trial many of his conjectures proved erroneous; the reader will find an interesting account of his intellectual character in Whewell's "History of the Inductive Sciences." "Having adopted as an hypothesis, the

central position of the sun, and the revolution of the earth and planets around this centre, he determined to discover the true nature of the planetary orbits, and find, if possible, some single curve which would explain the orbitual motions of the celestial bodies." His first theory was the circular one, and he invented nineteen hypothesis with respect to it, and devoted eight years of incessant labour to the examination. He subjected one hypothesis after another to the test of rigid experiment; and as they failed he consoled himself with the thought, that among all possible theories the mind could frame, one had been stricken from the list, and so a diminished number remained for examination; the subjecting of the hypotheses he invented to this scrutinizing he called hunting them down. The whole nineteen hypotheses failed, he could invent no more, he had exhausted every combination of circular motion his mind could suggest; he therefore abandoned this curve for the next simplest one; he again invented hypotheses and hunted them down, until the goal was won. "Triumph crowned the philosopher, *the orbit was found.*" Faraday says on this subject—"The world little knows how many of the thoughts and theories, which have passed through the mind of a scientific investigator have been crushed in silence and secrecy by his own severe criticism and adverse examination; that in the most successful instances not a tenth of the

suggestions, the hopes, the wishes, the preliminary conclusions have been realized."

The student, at the outset, must not be too ambitious in his aims; his ideas will naturally be immature, and can only ripen by studious and judicious exercise; consequently, as he desires and hopes for success, he must not at the outset attempt to rise into the highest region of discovery, he must not attempt what to him, for the present, will be unattainable. If he has not the advantage of a teacher, and if, in addition to this disadvantage, he has little time to devote to investigation, it would be a great advantage if he had access to one better acquainted with the science to aid and direct him in the selection of suitable and promising subjects for investigation. While no rules can be laid down for the discovery of truth, and each science can only be advanced by conceptions appropriate to it, yet the mind is capable of being so trained in a science, and habituated to reason about its facts and principles, that it necessarily forms, as it advances in knowledge, more and more appropriate ideas, conceptions, and speculations, with respect to the unknown as well as the known in that science; just as the mind, as it increases in knowledge in the every-day pursuits of life, gains more correct views and opinions in those pursuits; the very

made by those who not unfrequently have had no scientific training, indicates that with training how much more might be accomplished in the improvement and extension of manufacturing industries. Hence the importance of having our modes of teaching in as perfect accordance as possible with the laws of mental evolution. Students, especially those who have little time for investigation, evening students, for example, would, I think, be aided very much, and confidence in their own mental powers very much strengthened, if on their introduction into the field of original inquiry a plan was adopted somewhat similar in principle to the one followed in teaching qualitative analysis; in the latter case, as we have stated in the Fifth Lecture, a series of *artificial* mixtures the student has to analyze before he enters upon the analysis of substances, whose composition is not only unknown to him but also to his teacher, the composition of the artificial mixtures are known to the teacher as he prepares them, he has, therefore, entire control over the student's analytical examinations of these substances, and their composition is as unknown to the student as any unknown natural substance. I would, in the same way, give the student an investigation to work out that has already been done, but which is not known to him; simply

ascertain the results. This would promote that special training of the mind which is required in original investigation, for, as Dr. Gore observes, "Hitherto the nature and methods of original scientific inquiry have been insufficiently studied, and the success achieved in it has, therefore, been attributed too much to accident, to strong imagination, and exceptional natural ability; and too little to the less brilliant qualifications of steady thought, self-development, industry, and perseverance."

The establishment of evening scientific colleges, not for the teaching of the elements of the sciences, but exclusively for the cultivation of the highest branches of chemistry, and some of the other Inductive Sciences, would be a great step in advance of the evening instruction that is now given in any of our educational institutions; and would prove of great advantage to many who are engaged in industrial and scientific pursuits. It may be alleged that evening classes are already in existence in many of our colleges, as the Victoria University, King's College, London, Mason's College, Birmingham, &c.; it is true there are evening classes for teaching most of the sciences, and many other subjects in these and similar institutions, but they are mainly, at least, occupied in teaching the rudiments of the subjects they teach, which, I think, they ought not to undertake; that portion of the work they ought to leave to be performed

by the Primary Science Schools, they confining themselves to the highest branches of the respective sciences they engage to teach. It may be urged by some that the State could not undertake the establishment of these higher schools or colleges of science, because they could not be spread over the kingdom, but would have to be confined chiefly to the large manufacturing towns; but the same objection would apply to the establishment by the State of picture galleries, museums, libraries, &c., for they can only be established in the more important towns; and as yet, the endowment of such institutions by the State has been almost entirely confined to London; which ought to depend, from the great concentration of wealth in it, more to private munificence for such endowments than any other place.

The course of study in these evening institutions would have to be carefully arranged in order to render them successful; for not only is the capacity of the human mind limited, it being only able to take in a certain quantity of knowledge at once, but the amount of energy each person possesses is also limited; and as most, if not all, of the students in these evening colleges would have been engaged in some occupation or another during the day, it would have to be remembered in arranging the studies that a portion at least of the student's energies had been expended previous

to their entering on their studies at the college in the evening; this would also apply to the elementary instruction given in the less advanced evening schools.

It could not be expected that those who had been occupied throughout the day in teaching should also undertake these evening duties; for it would be absolutely necessary for any excellence to be attained by the learners that they should be able to devote several hours in the evening at the college on the study in which they were engaged, and that more than one night in the week would have to be devoted to it for its successful prosecution. Special professors or teachers would therefore be required to carry on this evening instruction; for of all the hindrances to the successful carrying out of such institutions none would be more fatal to success than that the duties of instruction should be *nominally* discharged by one, and the *actual* instruction be performed by another, who received no credit for it. Whether these evening colleges should be united with our present day colleges, or they should be separate and independent institutions, need not here be discussed.

I have already indicated the kind of work those studying Chemistry might undertake, and these investigations might be of very practical character; for example, those engaged in manufactures might

particular business, either in seeking to invent new processes or improving those already in use by rendering them more economical, or more effective in some form or shape. Some years ago I taught an evening chemical class in the Museum of Irish Industry, Dublin, and although it was necessary to teach the elements of the science to all who came, as they came with little or no knowledge of the subject, some who remained with me more than one session were able to carry out investigations which I believe have never been attempted in any other institution by a similar class of students. I will name some of the researches they published, because it will prove to those readers of the book who are ignorant of Chemistry that it is no chimerical sketch I have given as to what could be accomplished in evening colleges :—

(1.) "Comparative value of the different feeding substances for horses ;" this is a most elaborate paper. (2.) "Composition of linseed and rape cakes and artificial cattle foods selling in the Dublin markets." (3.) "On the composition of Drogheda ale." (4.) "On the action of air on alkaline arsenites." (5.) "On the composition and feeding value of Indian corn and some other cereals." (6.) "On the solubility of bone-earth in solutions of ammonic chloride and common salt of various strengths." (7.) On the solubility of granite in

estimation of tannin in some tanning materials."* (9.) The specimens of the different ores of iron, copper, lead, &c., and the specimens of coal deposited in the Public Museum connected with the Institution were quantitatively analyzed, and the analyses were chiefly executed by the evening students.

A very erroneous idea prevails as to the expense of keeping up a laboratory. During the time I was at the Dublin Institution £100 a year was allowed for laboratory expenses, and with that sum I found as many as thirty-four day students with all the apparatus and chemicals they required, and could at the same time obtain any expensive apparatus that became necessary; with an addition of £25 a year I was able to provide fifty evening students with all the apparatus and chemicals they needed. These *facts* show that the cost of keeping up a laboratory is by no means the costly affair, if well managed, that is generally supposed.

* There were other papers on the estimation of tannin; these papers I had repeated applications for from tanners in different parts of the United Kingdom; and some years afterwards the tanners formed a society for the purpose of trying to improve their manufacture, and they wrote to ask me if any of my students would undertake an investigation into the different methods for estimating tannin, and they were prepared to place a sum of money in my hands for the investigation. I greatly regretted we could not undertake it, as I had several students at the time quite competent to undertake the inquiry; but owing to the way the

LECTURE IX.

On Technical Education—School or College cannot be Substituted for the Workshop and Manufactory—Brain Work and Hand Work—Science and Practice—What can and what cannot be taught in School or College—Use of Tools not a Suitable Subject for Teaching Successfully in a College—Opinions of Scientific Men on the Teaching of Applied Science—The City Guilds Technical Examinations—Illustrations showing the Uselessness of a mere Verbal Knowledge of the Inductive Sciences—Manufacturers in the United Kingdom have hitherto not derived all the Advantages from Chemistry they ought—Why?—How the Chemical Student, intended for Industrial Pursuits, ought to be Educated—The Technical College of the Future—Handicraft, its importance—The Migrations of Industries—Illustrations that Knowledge is Power, and the want of it the Reverse in Industries—Technical Museums or Museums of Inventions—The Management and the Managers or Directors of them.

The teaching of Applied Science is a subject which is of great interest to most if not all of the inhabitants of the United Kingdom; "for if we are anything at all, we are industrial, commercial, and manufacturing. This may (the *Times* says) be a vulgar account of our vocation; but a nation which has to purchase half its food by the exchange of its wares for the products of other countries, and which cannot do anything great or grand without

spinning, weaving, mining, smelting, forging, rolling, turning, and grinding for it, must not despise mechanical and mercantile employments, or omit preparation for them. There never was so great a necessity for progress in scientific industry as there is at this day, though we cannot say that we discover a sufficient sense of the necessity."*

The provincial colleges, which have sprung up within a comparatively recent period by voluntary contributions, have all been started with the object of promoting technical education. Very much has also been spoken and written on the subject; but it is, I believe, beset with more difficulties to carry it out perfectly than many of those who have spoken on the subject appear to imagine. The giving of skill to the mind is not so easy a matter as the giving of skill to the hands; yet, if many of the speakers were to be taken as authorities on this subject, it would almost seem as easy a thing to accomplish the one as the other. A rudimentary education does not fit a man to receive that thorough and accurate scientific education which those who are to be directors, masters, managers, or improvers of industries require; and it is the education of these in pure and applied Science, and not the artisan, that we must look to, in the first instance, for improvement in and extension of our manufacturing industries.

* *Pall Mall Gazette*, January, 1874.

The school or college cannot be substituted for the workshop or manufactory; it is being attempted on the Continent, but whatever *seeming* success such institutions may have there, they are altogether unsuitable for us; the industrial conditions of our own and foreign countries being altogether different. Hitherto we have been *par excellence* the workshop of the world; and it is from the natural desire no longer to allow England to have this technical supremacy, that State workshops and technical schools have been established on the Continent, so that they might the more rapidly train workmen for the contest with us; and as "the *quality* of work is final—no nation being able to attain to more than well-designed and thoroughly good work—foreigners will pass us if we abate in earnestness and speed, but will overtake us if we keep at our best. We cannot reasonably expect for ever to monopolize the work of the world. . . . . No technical education in the world will avert the general diffusion of industry in Europe."* Between brain-work and hand-work there is a middle place, in which a knowledge of both kinds of work is required; for those who thus require a knowledge both of science and practice a part of their education can be best taught and learned in school or college; but much of the practical teaching of the applications of

* "Art: Pictorial and Industrial," 1871. Charles Burton.

science, or of knowledge of any kind, can only be properly and correctly learned by the learner taking part in the direction of practical work in which science and practice are combined ; by correctly learned, I mean in the way work of the kind is, and has to be, carried out in commercial undertakings where profit and loss cannot be disregarded. It is in our not correctly adjusting and dividing between the knowledge that can be best acquired in school or college, and that which—being of the nature of Art—is best learned in practice, that we are likely to commit many egregious mistakes in our rush after technical education. Practical men not unfrequently believe that the Arts as well as Science are capable of being taught in school or college ; and the teacher of Science not unfrequently attempts to teach the Arts which are the applications of that Science which he professes to teach. Our legislators commit still more fatal and injurious mistakes, by sanctioning and endowing crude, aimless, and expensive schemes of scientific education, instead of those that would be eminently beneficial to the nation ; what can be more absurd and preposterous than to suppose that Science teachers can teach one of the most difficult applications of Chemistry—that of its application to Agriculture—in twenty or thirty lectures, to boys and young men, and that students, after attending these

lectures and passing a written examination on the subject, will be competent to take part in improving the practice of Agriculture? "We do not appear in England," it has been said, "to have a faculty for organizing, discriminating, and rightly dividing functions. It is at one time all physical training, now all science, then all technical education. The hog, the whole hog, and nothing but the hog. Now the trades' guilds of old had special functions, and immense advantages would, no doubt, accrue to all crafts if the ancient and special functions of these guilds were revived—viz., that of collecting all information having reference to the technicalities of their respective crafts, and providing for their improvement, by the appointment of fit persons to investigate processes, to communicate the results of these inquiries, and to answer questions submitted to them.* . . . There are degrees and special functions even in the various crafts, a wholesome division of duties. The science and mental direction properly belong to the masters; skill of hand and eye, of handicraft, is another and distinct function, and belongs to the workman."†

* I think this suggestion as to the revival by the trades' guilds of to-day of the ancient and special functions of the trades' guilds of old is one that will commend itself to all who have given any attention to the important subject of Technical Education; and I think it ought to be pressed on the attention of the Members of the City Guilds.—R. G.

The College of Civil Engineers at Putney was established to prepare the student, by practical as well as scientific training, direct for his profession, so that there would be no necessity for him, after leaving, to become a pupil with an engineer, in order to learn the practical part; and if a scholastic institution could have combined PRACTICE with SCIENCE, certainly this, of all the institutions which have yet been established in the United Kingdom, was the one to have accomplished it. There were large workshops attached to the College, where practical work was undertaken commercially; the students had all the advantages of inspecting the construction of the work, taking part in it, and superintending it; yet the institution failed to turn out engineers. The students found, at the termination of their course of study, that they lacked the practical knowledge, and that to gain this it was necessary for them to become pupils under engineers. One of the most distinguished of the students gave me his experience, some years after he left the institution, as to what he considered could be, and what could not be, taught successfully in an institution of that kind. He was one of the few students who obtained employment as an engineer direct from the College. In the conversation, he told me he had learned, by experience, that the practical

institutions. They were extremely useful in preparing young men for the engineer; that was all they could accomplish. He selected his case as an example of the disadvantage of trusting entirely to an education of that kind. He said: "I have been engaged at a salary by an engineer; he therefore puts me to the kind of work, which is not practical, that I can do the best for him, and consequently I shall never learn practical work that a young man who enters an engineer's office as a pupil will learn in his first year." He said in conclusion, it is a mistake for any young man to remain too long in institutions of that sort if he intends to devote himself to practical pursuits. It has been attempted, on a much smaller scale, to teach *the use of tools* in colleges; but on the Continent, as well as here, it has been unsuccessful. Professor George Lunge, of the Chemical Technical Laboratory at the Polytechnic at Zurich, and who has had great experience as a chemist in English chemical works, stated, in a letter which was laid before the City Guilds Companies: "There is a workshop here where the use of tools is taught, *but this is no compulsory part of the course of studies; very* few avail themselves of it, and the Professors think very little of it, because the few hours that *can* be given to it by the students do not suffice to teach them anything worth the while."

Mr. Warington Smyth, Professor of Mining in the Royal School of Mines, in his evidence before the Committee of Scientific Instruction, spoke highly of the advantage of students coming prepared with *real practical knowledge* to that technical college. He said, "A few have come there (the School of Mines) after acquiring some practice, and those have generally distinguished themselves by taking good classes. . . . . I only wish that more of them could come prepared in that manner." Mr. Robert Hunt, Keeper of the Mining Records at the School of Mines, stated, before the same committee, "If I could do it, no man should attend the school in Jermyn Street (School of Mines) until he had worked three years underground, so satisfied am I of the necessity of combining practical knowledge with scientific acquirement." Sir William Thomson stated before the same committee: "I have a general feeling that a Chair of Technical Chemistry has nothing to teach that is not better learnt in a manufactory. There is only one Chemistry, and that is true Chemistry; and it is much more desirable, therefore, for those who are going into a chemical manufactory to know true chemistry, than that which would be of the most trivial value to them—namely, to have attended courses of lectures upon the processes of calico-printing and bleaching, and the manufacture of colours, elaborately described,

with illustrations, which the students are better able to see in the workshop."

I believe the Technical Examinations that are being carried out by the City Guilds of London Institute are not likely to prove of much, if of any, advantage to the country : I allude to the examinations in such subjects as brewing, calico-printing, iron manufactures, &c. Their inutility will arise not on account of any deficiency in the divisions of the subject examined upon, nor from the questions given, but from the slender stock of knowledge that is required for passing them : thus for the full technological certificate for brewing, it is required of the candidate that he has previously passed at least in the *elementary stage* of one of the following subjects at the Department of Science and Arts examinations :—

Machine Construction and Drawing.
Building Construction.
Theoretical Mechanics.
Applied Mechanics.
Inorganic Chemistry.
Organic Chemistry.

Of these six subjects only the last two would be of use in passing the examination on Brewing as given in the Programme of 1880 ; and the majority of the students who pass the Department of Science and Art examinations, at least in the elementary stage, have no practical knowledge

of the sciences they pass in ; they have acquired their knowledge generally, not by studying the science practically, but from books or lectures ; it is consequently not a knowledge of *things*, but only of *names of things.* It appears to me that in both sets of examinations—viz., those in *pure* Science, and those in *applied* Science—to employ the words of Professor Williamson, "It is just wasting the time of students, instead of doing that which really might be of permanent use to them ; and they are sent out as conceited fellows, who are simply a nuisance to the factory, if they do work in it, instead of modestly beginning to learn the practice at the bottom." Of what use, for instance, would this meagre knowledge of Chemistry be in the following case which occurred not long ago ? A brewer found all his brewings turning out unsaleable owing to the disagreeable smell and taste of the beer and its non-keeping qualities ; he soon saw it was a case that his practice could not solve, and as he had not been taught a smattering of science, he did not, as a smatterer would most probably have done, trust to his own knowledge, but he applied to one skilled in science, who found that the water he employed had got impregnated with sewage ; that was the cause of the serious loss he had sustained. Instances might be multiplied, and where less complicated processes than brewing were involved,

to show that the knowledge which is required in practice is very different from that which enables one to pass a written examination. A baker came to me some years ago. He had recently commenced business for himself. To his surprise and loss he found that, although he made excellent bread when a workman, he could only make very indifferent bread when a master, although he paid the best price for his flour. He had concluded before coming to me, that the other master bakers in the place had conspired against him, and got the miller to adulterate his flour. Although this appeared most unlikely, I examined the flour, but no adulteration could be detected. I inquired of him the kind of water he employed; he said an excellent well-water. On examination I found it was little better than filtered sewage. I recommended him to employ in place of it the water supplied to the town. On doing so his bread became excellent in quality. A gentleman who had studied Chemistry with me, turned his attention to farming, and observing in some of the agricultural journals that salt cake had been employed as a manure in some cases with advantage, he determined to give it a trial; he therefore sent an order for some to a leading manure merchant. On its arrival certain indications led him to suspect—which a test-paper confirmed—that it was not ordinary salt cake but nitre cake; this, if it had been applied to the

land, would have destroyed his crops. He employed it to kill the weeds on his walks; it not only killed the weeds but dissolved the stones. The manure merchant was not aware of the difference; he believed he had sent him salt cake. He certainly had—*but with a difference.*

The City and Guilds Institute would do well to abandon their courses of written examinations; for in written examinations the examiner's power of observing and experimenting cannot be ascertained, and yet observation and experiment, as we have already stated, are the fountains of the Inductive Sciences; and if the student has not acquired the power of observing and experimenting, which can never be acquired by merely reading or hearing lectures on Science, no written examination will qualify him to apply what he really and truly does not know. If with the money saved by the abandonment of these examinations they were to establish one or more efficient Primary Science Schools in unison with their Colleges of Science, they would have taken a great step in advance of the scientific instruction as it is at present carried on in the United Kingdom; a reformation that would prove an incalculable benefit to the nation, and one therefore which the members of the Guilds could look upon with the utmost pleasure and satisfaction.

Before entering upon the teaching of the In-

ductive Sciences in Technical Colleges, I may remark that by technical education I do not mean teaching a man a business; but I mean instructing him in Science in such a manner that he can practically and profitably apply it in his business; and it will here be appropriate to let the reader know what were the views of the late Professor Magnus, Professor of Technology in the University of Berlin, on this subject. He said that he "already detected signs that the new-born zeal for teaching Science in its application to the Practical Arts is encroaching on the domains of Science proper, and that it would thus deteriorate Science without at the same time advancing industry. The true work of institutions founded with the special aim of fostering the industrial Arts should be to insist on teaching principles, systematically, and not in their isolated applications. To treat of the applications of Science is, of course, necessary, even for the sake of Science itself; and under certain circumstances some of these applications may wisely be more dwelt on than others; but this is quite a different thing from pretending to teach as Science detached fragments of Science in their application to this or that Art.

Hitherto our manufacturers have not always derived from the chemists they have employed in their works all the advantages which Chemistry is capable of imparting in the carrying out of chemical

industries. I will point out some of the causes which have contributed to this defect: 1. There is frequently a manager as well as a chemist in chemical works; the manager is frequently unacquainted with Chemistry, but has obtained, generally by practice alone, a knowledge of machinery, the getting out of quantities, and the making of estimates: he consequently takes the direction of the works, and frequently will not let Science occupy its proper place. The chemist is usually confined to analyzing the raw and the manufactured substances; this, although important, is not all that a chemist should undertake in a chemical industry. 2. Frequently those who enter chemical works have a very imperfect and unpractical acquaintance with the science, owing to their not having given the necessary length of time to the study of it; perhaps it is also due in some measure to imperfect and unsuitable teaching. An *intelligent* rule-of-thumb man not unfrequently proves superior in every respect to a chemist of this sort. 3. But even with the best chemical knowledge a man is not fully or properly equipped for all the duties which he ought to be capable of undertaking, and ought to undertake, in industries which are the applications of chemical science. How ought he then to be educated?

It is a moot point with many who have given attention to this subject whether a man should

acquire the practical knowledge he requires before or after he acquires a knowledge of those sciences he has to learn. I prefer to illustrate my own views on the subject by one or two examples. I will first take the case of a young man, who intends eventually, when his education is complete, to be a chemist in chemical works. What subjects should he know, and how should he come prepared to the Technical College? He should have previously acquired a practical knowledge of Mechanical Engineering, both office work in the way of designing and estimating, and practical work in the workshop. Before entering upon his engineering course he ought to have been taught orthographic projection in the way a former colleague of mine, Mr. Binns, so successfully taught it at Putney College, and which he has given in his work on that subject. During the time he is learning drawing, and in the evenings during his engineering course, he ought to study, in a Primary Science School, Chemistry in the way I have described in the Fifth and Sixth Lectures, Mechanics, Physics, and also Mathematics, if he has not in his general education advanced sufficiently far in the latter subject; when thus prepared, he enters the Technical College.

In the college he should study the highest branches of Chemistry in the way I have described

given on the Applications of Chemistry; but they should be confined to recent inventions, not on what is contained in books on the subjects lectured upon; the student ought to study the books himself. He should go through a course of Applied Mechanics. It would also be very desirable that he should be taught the science of book-keeping; as it is most desirable that those who have the carrying out of improvements in manufactories, whether in the form of new inventions or improved processes of old ones, should know how to estimate the cost, and be able to draw out a correct balance-sheet.

He would, on the completion of his studies, be an excellent Chemical Engineer, fit for the post of manager in any kind of chemical works, as calico print works, alkali works, gas works, glass works, metallurgical works, breweries, &c., for he would not only have a sound scientific and practical knowledge of Chemistry, but also of all that related to mechanics in the way of machinery, &c. With such an education our young men would be more than a match, both in science and practice, for those trained in the continental technical schools and colleges.

Those who wished to be managers of mines ought to go through the same preliminary course as that for the Chemical Engineer; but, in addition, they should have practical experience of the

working of mines before going to the college. At the college they should study Applied Mechanics, Mineralogy, Physics, Inorganic Chemistry, Geology, and the Science relating to mining; and the subjects ought to be taught practically, and he ought also to be taught book-keeping.

Young men educated in the way I have described would be skilled and accomplished men of *practice*, as well as men of science. They would be able to learn by a careful inspection of any kind of chemical works sufficient of the practice of the process to undertake the management. They would by their practical and scientific knowledge see where improvements could be made in the process with commercial advantage, and in what direction the improvements ought to be sought for. And they would not fear, as the imperfectly educated manager too often does, to advise their employers to seek the aid of a scientific man, if they considered they had not the time, or had not sufficient skill to carry out the investigations in any branch of the process they thought was required. And by the competent advice and assistance they would be able to render the scientific man, he would be furnished with the knowledge which would be the most suitable for rendering the result of his investigation a *practical process.*

What an advantage it would be to most of our

colonies if, in addition to the kind of general education I have described, they had Primary Science Schools and Technical Colleges of the kind I have sketched out, in which their young men could be trained. It would be of great advantage to a country, whatever might be the nature of its natural wealth. Anyone who has had an opportunity of making himself acquainted with the manufacture of sugar, as carried on in the West Indies, cannot have failed to notice that one cause why the sugar-planters were not more prosperous, was due to the want of scientific and sound practical knowledge of those who had the management and direction of the industry. I believe the sugar-planters would find it most advantageous to themselves, if they were to abandon the practice of each estate manufacturing its own sugar; but that they simply grew the canes, and had a central factory where the canes of all the farms were sent to for the production of the sugar. Better skill and appliances could be obtained for such a factory than it is possible to obtain for factories of the kind at present existing on each estate. Here would be a grand undertaking to manage for the Chemical Engineer I have described.

If central factories were established, as they might most conveniently, in Barbadoes and the other islands, it would no doubt be a little more

inconvenient to establish solely one in Demerara; most advantageous improvements would soon take place in the manufacture; the juice would be thoroughly purified, and without the aid of charcoal; and when pure juice was obtained, boiling pans, simple in construction, yet possessing all the advantages of the vacuum pan, could be introduced, and the *natural heat*, as well as that derived from fuel, could then be employed in the evaporation. The result would be that the sugar would be of its natural colour, white; and molasses would be a thing of the past, for all the sugar in the juice would be obtained as sugar. The sugar planter need not then fear the sugar bounties of France and other countries.

Students coming to the Technical College prepared in the way I have stated from the Engineer's Workshop, and from the Primary Science School, would only require to devote themselves to a few studies; a comparatively small staff of Professors would, therefore, only be required. I would not have Botany or Zoology taught in a Technical College when Agriculture was not included in the curriculum.* It is not practicable to teach young men *efficiently* all the Inductive Sciences in the short time they can, as a rule, afford to devote to

* I was glad to find my view confirmed as to the undesirability of teaching Botany and Zoology in Technical Colleges by such an eminent authority as Dr. Percy.

education in these countries; and if they acquire a sound practical knowledge of two or three, they can easily acquire subsequently a knowledge of others, if they should require or desire to know them. The courses of Botany and Zoology given at the College of Science were regarded by many of the more intelligent students as little more than cram, and the great majority of the students have had no occasion for them in their after career. The student's attention ought to be concentrated during his stay at the Technical College on those it is necessary for him to know, rather than compel him to learn those it is very problematical he will ever require, and by doing so enable him only to acquire during the *time* he can afford to remain at the college a *smattering* of many sciences.*

Practice and Science must be united in teaching Agriculture; a special college in connection with a farm is therefore required in the teaching of the sciences that an agriculturist ought to know. But it would be very desirable that he should have been taught at the general school or the Primary Science School, Chemistry in the manner

* "The true policy is, not to teach too much, but only those few essential subjects which form the key to the rest; leaving much to be acquired, to choice, to individual energy. Then we shall have men's knowledge properly graduated to special purposes, and thorough technical education without any mischievous interference."—*Art: Pictorial and Industrial.*

have described in the Fifth and Sixth Lectures before proceeding to the Agricultural College.

I have remarked that the giving of skill to the mind is not so easy a thing as the giving of skill to the hands: but even manipulative skill can only be acquired by suitable training. More than once it has been attempted to establish cotton spinning at Liverpool, the seat of the cotton market; but the attempt has hitherto not been attended with success; it has also been attempted, I believe, at Bristol and some other towns, but with no better success; the trained skill for the work was not there, and there were none of the concomitant industries as exist at Blackburn, where the manufacture has been so long carried on. When new industries of that kind have to be started in places where they have not previously existed, the most successful method has been to import the trained hands, not only for the purpose of executing the work, but also for instructing the people of the neighbourhood. When a jute factory was started in the neighbourhood of Bonn some years ago, the trained hands were imported from England; and Mr. Whitworth, in starting cotton spinning at Drogheda, adopted the same plan. Chemical factories generally are started, when possible, in the neighbourhood of other chemical works, because the workpeople of the neighbour-

who start new industries in places where works of the kind have not previously existed, not unfrequently suffer considerable pecuniary loss at the commencement, especially if the process is at all a delicate one, by having to employ untrained hands. A case of this kind I was made acquainted with by one of the parties interested in the undertaking. He and another gentleman established Turkey red dye-works in a neighbourhood where the people had never been accustomed to that kind of employment; and it was long before they could get them to take the proper care in the different stages of that delicate process.*

Much that would be curious and interesting to many, and useful, at least, to the technical student, might be said of the kinds of hindrance which prevent or impede the introduction of new improvements. The requirement of extensive changes

* Our present Prime Minister, Mr. Gladstone, in some excellent remarks he made on handicraft at Chester in the autumn of 1878 observed—"What I want you to do is this: not to be in such a hurry to get into so low a class of head labour as copying clerks, or something of that kind. People should recollect that handicraft itself is capable of being raised to a very high description of art, and of yielding a very high standard of remuneration. I cannot tell you how anxious I am to impress that upon the mind of young people, and how certain I feel that the lesson is one of great importance to the people of this country. Let them perform their work in the spirit of an artist; let them try to give it excellence, and make a thing that not only will sell, but as good as they can make it, as useful, as well put together, as well proportioned, as pleasing to the eye, as full of beauty as they can make it; and the

in the machinery then in use, or an entirely new plant, often proves a fatal hindrance to the introduction of a new improvement; especially, if the improvement is offered at a time when the particular industry is more than usually prosperous. Much, also, that would be interesting, might be said on the migrations of industries, and the changing centres in which they locate themselves, and the causes which lead to the re-establishment of industries in localities where they had long been abandoned. The iron industry illustrates those changes more, perhaps, than any other industry; and in no locality is it more interesting to learn and study the changing nature of that industry and its vicissitudes, than in the district of Furness, North Lancashire, from the time when the Abbots of Furness were the sole makers of iron in the district to the present day.

It is scarcely necessary, at the present time, to say anything about the advantages of scientific knowledge, as it is universally acknowledged; but it may not prove uninteresting and uninstructive to many of my readers, if I give a few cases, that have not previously been recorded, to show that in industrial pursuits knowledge is power, and that the want of the proper knowledge is often attended with great pecuniary loss.

A London sugar-refiner gave me an interesting account, a good many years ago, of what occurred

on the arrival of the first cargo of sugar, made from dates, in the London market. This gentleman had not only learned how to boil sugar solutions in the vacuum pan, but also knew, as well as any of his workmen, how to treat all the different qualities of refined sugar that were manufactured at that time; for it was long before centrifugal machines were introduced into refineries. He had also acquired the knowledge of employing the polariscope in testing sugars. There was no other refiner in London at that time who could boil, or knew how to treat the different qualities of sugar, or knew how to use the polariscope. They were, in fact, entirely ignorant of their business; they consequently had to consult their sugar-boiler, who was always a German, before they purchased any sample; because, if they purchased without consulting him, and any mishap took place in the refining, he attributed always, whether true or not, the mishap to the quality of the sugar they had purchased. The German boilers, at that time, had only one way of testing the quality of unrefined sugar: they judged of it according to the size of the grain (crystal)—if it had a good-sized grain, they said it was "strang," if it had a small-sized grain, they said it was "not strang;" and they used to say they could do nothing with sugar that was "not strang." The date sugar was "not strang;" it was as fine as flour.

scope, and found it contained a larger percentage of sugar than the samples that arrived in the market made from canes. He then went to his boiler and asked him what he could make of it? He said he could make nothing of it. The refiner said he could, and if he purchased it he would take the pan. My friend knew there was not another refiner who dare purchase it, as his boiler would have condemned it; he therefore allowed it to remain in the market until it had gone down to the lowest point in money value; he then purchased the entire cargo, and made £10,000 by the transaction. The other refiners, he said, never allowed him the same chance again; they learned, from what he accomplished, that "not strang sugar" could be refined with profit.

Some years before the American Civil War broke out, a gentleman, who had a son studying Chemistry with me, called upon me one day, and during the interview informed me that another of his sons, who was in America, had met with a valuable lead mine containing 35 ounces of silver to the ton of ore: I made the remark that of course lead ores containing that amount of silver had been met with, but they were by no means common. He assured me there was no doubt about the matter; his son had had the ore twice assayed in America by two different assayers, and

contained. On the result of the assays, his son had engaged a party in England who knew how to separate silver from lead by the Pattinson process, to go out for the purpose of extracting it. The next I heard about the matter was, that the party who had gone out was considered to be an incompetent person, for he had failed to extract the smallest amount of the precious metal; the gentleman had therefore dismissed him, and was coming over himself, bringing a quantity of the ore with him, to learn how to extract it at the Mining Company of Ireland's Smelting Works at Ballycorus. On his arrival in Dublin he called upon me; he told me of the long journey he had had to undertake; the lead mine was at that time distant above 100 miles from any railway station. He related the difficulties he had experienced in getting his load of lead ore conveyed to the railway station, the long journey he had to make by rail, and then, in addition, to cross the Atlantic to attain the object he had in view. He had landed at Cork, and had left his load of ore to be sent on by goods train, he bringing with him three samples of it; he asked me if I would ascertain the quantity of silver. I made the necessary assays and cupellations, and with a result that I, knowing all the expense he had incurred, the toil he had undergone, and the sanguine hopes he and his parents and kinsfolk had formed of what would be realized

by the mine, could with difficulty reveal to him—his ore contained no silver. If that gentleman had known how to make an assay, and to cupel, that knowledge would truly have been POWER to him.

I have stated that managers properly educated would have no fear, whilst ignorant ones—ignorant, I mean, of the principles of the industry they were managing—would have, in advising their employers to obtain further advice in any difficulties that might arise in the manufacturing process, or in improving the process. The two following cases are illustrations of this.

A manufacturer of emerald green, and other colours, and who had studied Practical Chemistry in one of the London chemical schools, applied to me to see if I could devise a plan for him whereby he could manufacture that colour, which is composed of acetic acid (vinegar), arsenic, and copper, of different degrees of fineness; as the paper-stainers required for different kinds of work varying degrees of fineness in the colour powder. The English colour manufacturers cannot, like the French ones, employ acetate of copper in the manufacture because that copper salt in England is too expensive; the English manufacturer has therefore to employ sulphate of copper or blue vitriol, which is a cheaper salt. The employment of

process a more difficult one than when the acetate is employed. By the mode of making it from the sulphate then followed, it took from a fortnight to three weeks to make a batch of it; and at the end of that time the conversion was frequently not perfectly complete, especially in cold weather. The green was thereby injured in colour; sulphuric acid had in such cases to be added to improve the tint; but it also dissolved up a quantity of the green, which, as it could not be recovered, had to be run into the ditch. The process was therefore not only a lengthy one, but it was also an expensive one; and the degree of fineness of the substance could not be foretold. By employing the same substances in the manufacture, but altering the mode of making it, I was able on the manufacturing scale to make the colour in about one hour, and the conversion was always perfect; no sulphuric acid had consequently to be added, and the coarseness or fineness of the substance was under entire control.

The Directors of a Soap Company applied to a firm of Tallow Brokers to let them have tallow to a large amount in money value (£20,000) on credit. They replied that if, after my visiting the works, I could assure them the manufacture was carried on properly as a commercial undertaking, they would do so. The Directors said they manufactured their soap by a secret pro-

cess, and therefore they could not allow me to inspect their works. It was finally arranged that I should be admitted to that part of the works where the making of the caustic alkali was carried on, which they considered did not form part of the secret process. On visiting the works I saw that before employing the alkali solution they evaporated it to a certain strength; *that fact* revealed to me their plan of making soap. I found the party who was considered by the company to be the inventor of the plan, and who was not only their manager but also their dictator, knew really nothing of the true principles of the process, and was either too blind to his own ignorance, or too much afraid of anyone with superior knowledge being consulted by the directors, that he left them in perfect ignorance of the difficulties that beset him. I saw that he, not knowing how to work up the weak alkali liquors without filling the factory with evaporating pans, which would have revealed to the most ordinary intelligence there was something radically wrong in the process as it was carried on, had constantly one-half the alkali made thrown into the ditch; and he was so ignorant of the conditions to be observed in making it, that he could only manufacture it from the most expensive carbonate. I, of course, advised my friends not to advance the tallow, and very soon, as might be expected from such ruinous

waste, the company became bankrupt, and all the money of the shareholders was lost.

It was, in one sense, very amusing to learn the reasons he assigned to the directors for any mishap that occurred in the manufacture, and *that they believed him.* When the alkali, for instance, came out on the surface of the soap like hoar frost, he used to tell them it was due to some essential oil they had purchased for perfuming the soap. The directors became so alarmed at the injurious effects their supposed wrong purchases entailed, they at length deferred to the superior wisdom, as they believed, of their manager, and left to him the purchase of the materials. I may add he was not a native of the United Kingdom.

I have stated in the Preface to my "First Step in Chemistry" that those who seek to become directors of industries should have a real knowledge of the science of which the industries they seek to direct are applications; and that large, and often injured class, shareholders, will I think agree with me—the non-success of many companies and also private undertakings is due, not unfrequently, as in the case I have just described, to ignorance and incompetency.

Another case, not less instructive as to the necessity of one or more of the directors of a chemical industry having a knowledge of the principles of the science on which the industry is

based, for its profitable working, came under my notice a few years ago. The company was not very prosperous; it was being worked at a loss, and only ordinary workmen were employed to manage the factory. There occurred in the manufacture, a mixture of different soda salts as a bye-product; carbonate of soda was one of the soda salts, and it was present in the mixture to the amount of about 15 per cent. There was no sale for the mixture where the factory was situated, and the selling price at a distant market scarcely covered the cost of transportation. One of the workmen informed the directors that he had a plan for making it profitable—he would make *magnesia* from it; and all that he wanted in addition was a *single* tub of sea-water to start the process. Once started *no more sea water* would be required. There was no impediment about procuring the water, for the factory was situated on the sea-shore.

I received an invitation from the directors to accompany them to see this wonderful invention. Before the time arrived for the visit, I saw the workman, and I told him, if he was not deceiving himself he was certainly going to deceive the directors. I inquired of him why he wanted one and only one tub of sea-water. He could not tell me. I then explained to him that what he was seeking to make was carbonate of magnesia; that

the magnesia was in the sea-water, and the carbonic acid in the soda salts; and the water was, therefore, as necessary as the soda salts for the continued production of the substance. He then informed me that he had only been told about it; he had not seen it worked. I did not accept the invitation of the directors, as I did not wish to embarrass the workman by my presence; but I was curious to learn what he said or what he did. He was equal to the occasion: he did not tell the directors that he had found he was wrong, and that the sea-water would be required continually, for that would have been to confess that he had been ignorant of the manufacture he had proposed. He got out of his difficulty, and, at the same time, did not damage his skill in the eyes of the directors, he found, he said, the sea-water was too weak there, and they would have to establish the factory on a distant island if they wanted to work it successfully; he knowing perfectly well that they had no money, if they had the inclination, to do that.

Several of these directors had received a University education, and yet they were so destitute of the knowledge of Natural Science, that they did not see that if he only, as he stated, required one tub of sea-water, and if he was really correct, which he was not, in what he stated about the weakness of the water there, it could have been

with very little expense rendered stronger by evaporation. If these gentlemen had been asked did they believe the man was capable of making something out of nothing, or that he could transmute one element into another; they would no doubt have answered correctly, but that was really the experiment they went to see accomplished. The single tub of sea-water obstructed their mental vision. The industry under such guidance, I need hardly add, failed. It is not, of course, to be expected that those who do not pursue the study of the science after they leave school or college should be, as it were, walking dictionaries of chemical knowledge, but if the science was one of the subjects taught as a branch of general education, *and taught properly*, they would ever remember the principles as they remember that two and two make four and not five; and if they desired it they could as easily return to the study of it as to the study of arithmetic.

I will relate one other instance as an illustration how easily those who are termed practical men, men engaged in business, are duped if only impossibilities in anything that relates to Science are proposed to them. Whereas if a scientific man proposes or submits to them in the way of improvements what is real and practical, they generally regard him as an unpractical man and not unfrequently as a visionary; for he cannot boast like

the charlatan and impostor, as his knowledge of scientific truths restrains him; and thus not unfrequently impudence succeeds, and gets the better of modesty and truthfulness.

Soon after quartz-crushing machines were invented, an American arrived in London with one of his own invention, and having engaged a place near the Royal Exchange, gave a free invitation to all to come and see the operation at work of grinding quartz and other rocks to powder and extracting silver, and frequently gold, from them, which he assured his visitors all rocks and soils contained, and in sufficient quantity to make it profitable to extract the metals.

The powdered rock was treated in the machine with quicksilver, which has the property, as most people know, of taking up other metals—dissolving them, as it were. The metals which the mercury dissolves can be separated from it by subjecting the mixture to distillation; the mercury distils over, while the other metals, those it has dissolved, are left behind in the still or retort. Silver was always found to be present in the rocks the American crushed, gold not always but *very* frequently, and the metals were present in quantities that would make it very profitable to extract them. The American wished to sell his invention; the price was £30,000. Before, of course, the wise

there was no deception about it. The first thing they did was to send samples of some of the rocks to the two best-known assayers in London. Both assayers stated they could find neither silver nor gold. The American stated that his process was more delicate than that of assaying; he therefore recommended them to select someone to distil the quicksilver. They did so, and it was found there always remained in the still silver and very frequently gold.

The invention was purchased, and the inventor departed and left the purchasers to do what they ought to have done before the purchase—viz., to have the rocks ground by employés of their own; when they did they found the precious metals had departed with the gentleman.

It was afterwards tried by the aid of these machines to convert some of the English copper mines into gold mines. There appeared in the *Pall Mall Gazette*, on January 25th, 1872, an amusing letter on the subject, headed "A Mining Adventure."

These cases teach, if they teach anything, that for the better progress of industry in the United Kingdom, there is required, if for no higher reason, a better system of general education than is generally to be met with at present—better Primary Science schools than now exist; and the

necessarily be attended with great improvement in the higher schools and colleges of Science.

I cannot close the subject without making a few observations on Museums as Educational Institutions, especially on that class whose contents are more or less of a technical character. I would replace the latter with what might properly be termed Museums of Inventions.

Museums, with the exception of those devoted to Art, as regards their contents, have been generally constructed, it may be said without any exaggeration, as if they were intended for the idle and purposeless. If those who visit such museums were asked with what object they visited them, it would be found, I think, that by far the largest number went for the purpose of killing time, or from mere idle curiosity. The want of attraction in such Museums for those who ought especially to benefit by them, not unfrequently arises from the heterogeneous nature of the collections, and from the absence of all systematic classification of the exhibited articles; and when the collections are mainly, if not altogether, of a technical character, they consist, not of new inventions and new raw materials, but of antiquated models of machinery, or models which almost every one connected with the industrial arts are thoroughly conversant with, and the raw and manufactured

materials exhibited are chiefly of a kind which can be seen in greater variety and excellence in the factories or shops in which such articles are manufactured or sold.

Museums of Inventions should be of a totally different character. They ought to contain models of all the most recent mechanical and other inventions, and when the inventions become adopted the models should be removed; as their utility and their perfections and imperfections could be better studied in the factory or workshop where they were in use. Along with the models there ought to be specimens of all raw materials which had not hitherto been applied. And in connection with such Museums there ought to be a Library of Patents, so that the man of industry, the inventor, and the student of applied science, could consult the patents in connection with the models, &c. exhibited, as well as for other objects. When possible, such Musuems ought to be in connection with Technical Colleges.

There ought of course to be exhibited in such Museums the mineral wealth of the part of the country in which the Museum was situated; the specimens of the different ores and coal ought to be average specimens, and their chemical composition ought to be stated on the labels.

a technical point of view, would find their place in such a Museum, as for instance a collection of specimens exhibiting the different styles of calico-printing required by the different Nations.

The Manager or Director of such a Museum to be suitable for the office would require more varied qualifications than the teacher or examiner; he ought not only to be an educationist, but he ought also to have had considerable practical experience in the industrial world.

LECTURE X.

Our Educational Institutions and our Educational Resources—The University Local Examinations — Inspection and Examination of Schools by the Schools Examination Syndicates of the Universities of Oxford and Cambridge—The Higher Local Examinations—University Work in Great Towns—Technical Education and the Examinations in Technical Subjects carried on by the City Guilds—The Reforms required—The Department of Science and Art—Origin of the Committee of Council on Education—Its Connection with the Privy Council an inconvenience and an evil—The Complication of the System of the Education Department—The different Institutions and Subjects the Lord President and Vice-President are charged with—The Necessity of having a Minister of Education—The Science Schools under the Department of Science and Art—The Inspection and Examination of these Schools ought to be combined—A Plan proposed for effecting this desirable Reform—Other Reforms pointed out.

In the first Lecture I have attempted to place before my readers some statistics for the purpose of acquainting them with the amount of money that is expended on education in the United Kingdom, and I think we must all confess with Dr. Wiesse "the results are glaringly disproportionate to the enormous sums spent upon the education of young Englishmen: there is no department of human energy in which there is such a pretentious

display of power with such a *beggarly* amount of result." In noticing the Reports about our public schools, the same eminent educational authority makes the following observations, which are without doubt grave and serious ones for us as a nation: "The Reports and the actual condition of the schools furnish abundant materials; *but where is the* ARCHITECT to construct out of them an edifice worthy of the *greatness of* England?" In another part of his valuable work he remarks: "When we compare this state of things (the unity of administration in German schools) with that which at present exists in the English school system, I can scarcely say otherwise—and Englishmen themselves have used the same expression than that things are in a *chaotic state*, the very reverse of organization. There is an absolute want of any clear division of the whole domain, of a definition of the different kinds of schools, and of fixed distinct objects. In many cases we ask in vain for some decisive authority which would prevent freedom from degenerating into arbitrariness. It is true that an extraordinary amount is done, *that ample means exist and are contributed with great liberality for scholastic purposes; but they are frittered away.*"

"The affairs of education and culture, and the science and art collections, are in very different hands and belong to separate departments, which

are quite independent of one another. Hence, in these matters, one everywhere misses *unity* and combination of the powers of administration. WHAT GRAND THINGS MIGHT BE ATTAINED, could the means be kept together and employed according to some *fixed plan of unity!* The many noble endeavours and unselfish contributions towards the great object of education are, as they stand—isolated, atomistic—not nearly so effective on the whole *as they might and ought to be.*"*

In this Lecture we shall notice and discuss some of the efforts made by the State, by our Universities, and by the City and Guilds Institute, to improve the general and scientific education of the country, independent of or in connection with our Grammar and other Public Schools and Colleges, which are supported by private endowments or Government grants. We shall also point out the absolute necessity there exists at the present time for having a special Minister of Instruction, owing his appointment solely to his great attainments and capability for the office, and not from any party considerations.

The Universities of Oxford and Cambridge

* Dr. Wiesse has made a personal examination and inspection of our educational institutions on two different occasions; his last visit was in 1876, his previous one in 1856; his personal acquaintance with our educational systems and institutions, combined with his great educational experience of the systems and institutions in his own country, ought to render the opinions he has expressed with regard to our own of very great value to us.

established what are termed "Local Examinations" in 1858, to supply a common test of attainment for boys both in our public and private schools. Two sets of examinations are held in different central localities—the first for junior boys below the age of fifteen, and the second for seniors or boys below the age of eighteen. The examinations were subsequently extended to girls who are also divided into juniors and seniors. Other Universities have followed the example set by Oxford and Cambridge. The examinations are conducted by means of *printed papers* set by a central body of examiners, who are elected by the syndicate of the University from among the Fellows; the papers are worked by the candidates in the presence of superintending examiners appointed by the Universities. To the British Colonies the examination papers are sent out in all directions. The pupils can be examined in the ancient and modern languages, in the deductive and inductive sciences, in scripture, history, and geography. The University of Oxford confers on those who pass the senior examination satisfactorily the title of Associate in Arts; to the juniors who pass, a Certificate is granted. Cambridge and the other Universities give simply a Certificate to both classes. Besides the diplomas and certificates, prizes, as books, instruments, and scholarships, are also publicly given to the successful pupils.

Oxford holds an examination when a local committee is prepared to undertake all those expenses which are occasioned by the examination being *local*; and Cambridge when twenty-five fees are at least guaranteed. To meet the expenses which have to be borne by the local committee, as stationery, rent of rooms in which the examinations are held, &c., a local fee, which varies at the different centres, is charged to each candidate in addition to the University fees.

Educational reform in England has taken place in respect of the lower and higher classes, but not as regards the middle classes; the latter, it may justly be said, have to pay their share for the education of both the other classes, but in return they receive little or no State aid themselves. The teachers in the primary schools have been trained at the expense of the State, and the schools are likewise inspected by salaried official Inspectors; the upper classes enjoy the advantages of the richly endowed Public Schools and Universities, but if it were not for private munificence in the past and present endowing local grammar and other middle class schools, the middle classes would have been left almost entirely for the school education of their children to private, or, as they have been termed, adventure, schools. The Local Examinations are an attempt on the part of the Universities

labour under with respect to education. But the Universities have no power to compel schools to have their pupils examined; it is purely optional with the school authorities whether they submit any of their pupils to the examinations or not; but even when they do, they have not, in these examinations, their whole school examined, but only such of their pupils as they themselves select; this induces teachers to devote their time to the *clever* boys of the school and to neglect the rest; this tends to lower rather than to raise the standard of education *for the many*, which cannot be regarded in any other light than as a National injury. The *Saturday Review*, in writing on this subject in May, 1861, stated that as a permanent test, it considered it an unjust one; an unjust test, it said, must work mischief. Another element of unfairness, it stated, arises from the immense fluctuations of the standard which the sudden veerings of the "pass" and "pluck" lists reveal, and which are almost inevitable in the case of examinations conducted on so vast a scale by a body of examiners who must be frequently changed, and who will often, as academics, be unused to examining boys in elementary subjects. Nor, we confess, is it without some misgiving that we see so direct a control over the subjects of middle class education, permanently assumed by men whose own knowledge and experience lie in a different sphere."

As the pupils have to go to the examiners and not the examiners to the pupils, it must prevent pupils being sent from many schools in out-of-the-way districts distant from, and inconveniently situated as regards the "Central Locality." Moreover, inspection of the schools should be combined with their examinations, and the examiners should always be the inspectors. The Marquis of Hartington, in a speech he delivered (July, 1878) at the distribution of prizes at the Eastbourne Centre, referred to this question of inspection and examination; he said: "Another point is, whether any thoroughly satisfactory results can be achieved by a mere examination, without inspection of the schools themselves." I have in a former lecture pointed out the utter inadequacy of written examinations for testing the knowledge of the examinee of any age in the inductive sciences.

Taking Dr. Wiesse as the exponent of opinion of the German educational world on these examinations;—"the question, however," he observes, is: "Is it the business of a University, as such, to occupy itself with these things (putting questions on elementary subjects) in the manner in which it is done in England? We in Germany are of opinion it is not; in England, on the other hand, the voluntary action of the Universities in the affairs of the schools is approved of, though not

arrangement an equivalent for the official objectivity with which a perfectly independent school authority proceeds. Nor is it the same as the arrangement in Bavaria, the only large State of Germany that has no permanent department for the government of schools provided with technical powers; for these commissions, composed of professors and teachers, are appointed from time to time to deliberate about school questions, or to visit schools in the name of the Government; for such visits the schools have, of course, not to pay anything."

In 1877, the Oxford University authorities examined, under this scheme, 1,670 boys and 634 girls; and Cambridge University authorities examined no less than 4,681 candidates, of whom 3,002 were boys and 1,679 girls.

Inspection and Examination.—In 1873, Articles of Agreement were signed between the Schools Examination Syndicate of the University of Oxford, and the Schools Examination Syndicate of the University of Cambridge, by which they should act in concert in the examination of schools. The school examination to be one or more of the following kinds:—

(*a.*) Such an examination in the general work of the school, extending either to the whole school, or to portions of the school, to be selected

examiners to report generally upon the school work.

(*b.*) Such an examination in any main subject of instruction extending either to the whole school, or to portions of the school to be selected with the approval of the Board, as will enable the examiners to report on the standard reached in that subject.

(*c.*) Such an examination of the highest division of the school as will enable the examiners to report upon the general work of that division, and, if required, to place the boys in the order of merit, and to award exhibitions, scholarships, and prizes.

Applications to the Board for the appointments of examiners, shall specify the kind or kinds of examinations desired by the authorities of the school.

This Examining Board unites inspection and examination of the schools examined under this scheme, the examiners going to the schools, and not as in the Local Examinations the scholars going to the examiner. School authorities cannot, of course, be compelled by this Board to have their schools inspected and examined; and those who request an examination need only have a portion of their schools examined. The same subjects are examined upon as in the Local Examinations.

The Certificates granted give exemption, under certain conditions, from many examinations as the

first examinations in the University course at Oxford and Cambridge, and the matriculation examination of some of the Colleges and Halls; the Preliminary Examination of the College of Surgeons; the Preliminary Examination of the General Council of Medical Education; and the Preliminary Examinations of the Incorporated Law Society; candidates for first appointments in the Army and for admission to the Royal Military Academy, Woolwich, who have obtained Certificates, are exempted, at the discretion of the Civil Service Commissioners, from the non-competitive portions of the examinations prescribed in the Regulations of April 1873, so far as the Certificate shows that the candidate has satisfied the examiners in the subjects included in these portions of the examinations. From the Returns that have as yet been published, it appears that the leading Public Schools have obtained the greatest number of Certificates; thus, in 1877, Eton College obtained 37, Marlborough College, 22, and Rugby School, 21. In 1878, Eton College again obtained 37, Marlborough College, 27, Harrow School, 24, and King's College School, London, 23.

It would be most desirable for the advancement of middle-class education in Ireland that the present mode of conducting the Intermediate Schools Examination in Ireland should be changed,

inspection and examination corresponding to the one just described, but more complete.

'The University of Cambridge has recently established what are termed "Higher Local Examinations." They correspond to the Local Examinations already described with respect to the subjects examined upon—the establishment of Local Centres, &c. They are open to all persons, male and female, who have completed the age of eighteen years.

The University of Cambridge commenced the organization of a scheme in 1875, for extending University teaching into populous towns; and the University of Oxford has lately appointed a Delegacy to arrange for carrying on a similar scheme in towns unconnected with Cambridge, the object being, to enable those who have left school, and are unable to go to a University, to go on with their learning, by placing within their reach higher education of an accurate and methodical kind. The teachers are Graduates of the University; the instruction is given by lectures and in classes. The following are the University regulations for conducting the lectures and classes:—

"The teacher to remain in the lecture-room for some time after the conclusion of each lecture and class, in order to answer questions, or solve the

to give advice as to the reading of text-books, and other means of sufficiently studying the subject.

"Each lecture to be accompanied by a syllabus distributed to the pupils, and by questions. Those who desire to answer these questions to do so in writing at home, and to be at liberty to submit their answers to the teacher for correction and comment.

"The class, in each subject, to be formed only from among those who attend the lectures on that subject, and to consist of those who are desirous of studying it more fully. The class, at the discretion of the teacher, either to take up the subject of the lectures, or cognate subjects bearing directly thereon, and necessary for the better elucidation of the subject of the lectures. The teaching in the class to be more conversational than that in the lecture."

The lectures and classes are given once a week, and they extend over a period of three or of six months; and there are evening as well as day courses. Those who have attended the lectures and classes for twelve weeks can be examined by examiners appointed by the Syndicate, and if successful at the examination, are granted Certificates. The sum payable to the University for a complete course of three months' lectures and classes, and the examinations and certificates in

addition to this there are the local expenses, consisting of—

1. Hire of rooms.
2. Advertising and printing.
3. The proportionate share of the railway expenses incurred by the lecturer in travelling between towns co-operating.

The subjects hitherto lectured upon were the following:—Political Economy, Logic, Origin and Growth of Language, English Literature, French Literature, English Constitutional History, the Social History of England, History of the French Revolution, Physical Geography, Geology, Chemistry, Light, Spectrum Analysis, Heat and the Conservation of Energy, Astronomy, Elementary Mechanics, &c.

Some doubt whether the curriculum of studies pursued at the Universities—in other words, University education—would be the right kind of education for those engaged in industrial pursuits. It is certain that the modes of teaching many of the subjects, especially the Inductive Sciences, must be different in the one case to that adopted in the Universities themselves, if "University work in great towns," as it is termed, is ever to be of any advantage to the spread of sound education amongst that portion of the industrial classes who are not able, from want of means, to attend either the older or younger Universities

and Colleges which are now so comparatively abundant in England. The methods, I have said, for teaching many of the subjects must be different to those followed at the Universities, for the Industrial students will not be able, like the students at the Universities, to supplement the deficiencies of the system by resorting to tutors or grinders for further instruction.

From a Paper on this subject, "University Work in Great Towns," by Mr. J. G. Fitch, in the *Nineteenth Century*, Nov. 1878, it would appear that after the novelty of the experiment had ceased, the number attending the lectures and classes decreased rapidly. In the winter of 1875–76 lectures and classes were held in thirty towns, and the attendances amounted to 7,000; and 1,700 students presented themselves for examination at the end of the two terms of 1876. But in the next year the figures showed a considerable diminution, only 5,002 attended the lectures; and the number of candidates for examination fell to 634 in the former half of the session, and to 441 at the end of the latter or Lent term. And Mr. Fitch observes that it seems probable that the statistics of the session just concluded will reveal a further diminution. In Bolton, the number of tickets sold in the first term of 1875 was 458, in the corresponding term of 1876 was 263, and in the spring term of 1877 had

become reduced to 143. In Leeds, the number of students who attended the lectures was in the session 1875–6 as high as 998; but in that of 1876–7 it fell to 369. In Bradford the scheme broke down hopelessly after a single trial. The attempt to plant it in London, Mr. Fitch states, has so far met with very little success. Two local colleges, one at Nottingham and the other at Sheffield, have been established and endowed in connection with the scheme. The Marquis of Hartington, in speaking of this University extension scheme at Nottingham, remarked: "This superstructure of higher education we are attempting to raise will have to be raised in *too* many cases *upon the frail, sometimes I fear rotten, foundation of inferior middle-class schools.*" I have no doubt, from my own experience, that defective preliminary education, pointed out by the noble Lord, has had to do with the failure, but it cannot be the sole cause.

The written answers on several subjects, according to the Reports of the Examiners, contained not much more than a reproduction of what had been said by the lecturers; they were "a repetition of formulated phrases in place of an intelligent assimilation and reproduction of their general purport." "The true test of the value of the system," Mr. Fitch states, "came when serious study was demanded and novelty had worn off. It was discovered, in some cases, that the subjects of instruction were

unsuitable ; in others, that the lecturers, however well qualified by the possession of the needful knowledge, were not skilful teachers, and did not succeed in sustaining the interest or responding to the actual wants of their classes. In Chester, the class of Geology, promoted mainly by a few young workers whom the late Canon Kingsley had gathered together *for reading and field excursions*, was maintained with difficulty for a single session, and was not resumed."

I think one chief cause of the comparative failure of this scheme has been due, as Mr. Fitch has stated, to the unskilfulness of the teachers ; it requires more than an ordinary teacher to teach those who come to the class more or less wearied with prior labour, either of brain or hand work, and who have expended on their daily employment a great part of their energy, and who have, in addition, little leisure, beyond the time they give to the class, for study. The teaching, when it has, from the nature of the subject, to take the form of lectures, ought to be catechetical ; and the Inductive Sciences ought to be practically, and not theoretically, taught ; if, for instance, the plan of teaching Geology adopted by Canon Kingsley was replaced by mere lectures, and given by those who had little or no practical knowledge of the subject themselves (*see* pages 75 and 76), it is not surprising that the class vanished.

I have directed the reader's attention, at pages 12 and 377, to the Technical Education the City and Guilds of London Institute have commenced. Their examinations ought to be combined with the inspection of the schools and classes; and the teachers ought to be paid partly by salary and partly by fees, and not on the result system. The inspection and examination would not be more costly, nor perhaps as costly as the plan at present in use, whilst it would be far more efficient. In discussing the educational plans of the Department of Science and Art, I will point out a plan for the efficient inspection and examination of these classes.

In describing the education system undertaken by the Department of Science and Art our remarks will be confined to the Science division principally. This department was established in connection with the Board of Trade in March, 1853, as a development of the Department of Practical Art, and was placed under the direction of the Committee of Council on Education in 1866. The Science division is prepared by its certificated teachers and its examiners, to instruct and examine pupils in any part of the United Kingdom, in a variety of subjects, including all the Deductive (excepting Logic) and Inductive Sciences, and the applications of those Sciences, also Practical Shipbuilding, Building Construction, Machine Construction

In inquiring into the machinery of this department and the means it adopts for teaching and testing the knowledge of its pupils, we will commence at the fountain-head. The political chiefs are the Lord President of the Council (who is always a Peer) and the Vice-President (the Vice-Presidentship was not created until 1856), who is a member of the House of Commons, and of course a member of the Government for the time being, but who has only on one occasion been a Cabinet Minister. They have the control not only of the Science and Art Education of the country, so far as it is administered by the Department of Science and Art, but they have the management of the National Education of England and Wales; and I am not quite certain whether they have not some control over the National Education of Scotland. I need hardly remark that they go out with each change of Government.

"It was, we believe," states the *Edinburgh Review* in 1861,* "far more by accident than by design that a Committee of the Privy Council and a branch of the Council Office have gradually assumed the functions of the department of Public Education. In the year 1838 a letter was addressed, by Lord John Russell, then Home Secretary, to the Marquis of Lansdowne, then Lord President of the Council, proposing that 'a

* A Review of the Report of the Commissioners appointed to

Committee of Council should be appointed by Her Majesty, consisting exclusively of members of the Government, for the purpose of considering all matters affecting the education of the people, and of superintending the application of any sums which may be voted by Parliament;' and in pursuance of this recommendation an Order in Council was passed in 1839 constituting such a Committee, but the words 'for the purpose of considering all matters affecting the education of the people' were omitted from the Order; and we have the authority of Lord Lansdowne himself, in his speech of the 5th July, 1839, for stating that the functions of the Committee were confined to superintending the distribution of grants. Lord Lansdowne declared on the same occasion that a permanent settlement 'was at present quite out of the question, and that the present arrangement was of a temporary nature, liable to be modified at pleasure, and revised at any moment, or enlarged if it should be found to work well for the country.'"

That Committee of Council has been charged since 1839 with the distribution of a grant which has risen from £30,000 (primary education) to £2,646,820 for primary education in Great Britain in 1879, and for the Department of Science and Art, £307,414; making a total of £2,954,234. "The Committee of Council is supposed to consist of several of the most distinguished Ministers of

the Crown for the time being. Everything done is done in their name. . . . . If the truth be told, the connection of the Committee of Education with the Privy Council is purely nominal and imaginary. It occupies rooms in the same office; it originally employed some Privy Council clerks, none of whom now remain in its service; its responsible head is the Lord President; some of its appointments are made by the Queen in Council; but in all other respects it is as distinct from the Privy Council as the Board of Trade, which was also a branch of the Council Office in former times, and still retains the title of a Committee for Trade and Plantations. The Privy Council is essentially a deliberative and in part a judicial body, whose duty it is to advise the Sovereign, more especially in the exercise of the prerogatives of the Crown. It is a great office of State; its President is the second layman in the order of precedence, and always a statesman of high rank, both social and political; it has (with slight exceptions) no inherent executive or administrative functions, duties, or powers; but it serves principally to give to the measures of the executive departments the form and authority of acts of the Sovereign. Clearly an office of this character, and thus constituted, had no connection whatever with the business of popular education; and the more the Education Committee became surcharged

Lords of the Privy Council to deal with them. . . . . In addition to these considerations, we agree with Mr. Chester in his evidence, that the system of placing the education of the country under the control of a department of the political Government is vicious in the extreme.

"We have said that we think the establishment of the Committee of Council in 1839 was favourable to the cause of liberal education, especially in the battle which shortly afterwards ensued; but since the Committee of Council has become, what it has now been for many years, a mere administrative Board, we think that its nominal connection with the Privy Council is an inconvenience, an evil, and to some extent an imposition on the public. The Committee itself has, of course, been less and less frequently convoked, and never except for the consideration of some general minute. The Lords President, being charged with numerous and weighty cares of State, have neither time nor inclination to conduct the intricate petty details of an overloaded department. Indeed, it has been thought necessary to create a new political office, styled the Vice-Presidency of the Committee of Council of Education, with a salary equal to that of the Lord President himself, for the express purpose of relieving the Minister, and conducting the Educational business in the House of Commons. But the actual result of this

executive department with machinery entirely unfitted to the purpose, is that the department has had to create its own machinery; in other words, it has become the most entirely *bureaucratic* of all the offices now existing in this country; and we mean by that term an office in which the subordinate members of the department do in reality exercise an almost absolute authority under the 'clarum et venerabile nomen' of the Privy Council of England.

"Mr. (now Sir R. R. W.) Lingen (the then Secretary of the Committee of Council on Education) has himself stated in his evidence that 'Vice-Presidents, who have been in the Committee of Council and have seen other departments on a large scale, state that the complication of this system is far greater than they have seen anywhere else.' . . . . Offices, which exercise, as they do in continental administration, an immense amount of central power over minute details, have a constant tendency to render that power more engrossing and absolute. The Department is, we believe, the only public office in England which attempts anything of the kind. It is of the essence of English administration, as contrasted with foreign bureaucratic administration, to leave details, in great part, to local agents and authorities. The consequence is, that the establishment of the Education Department, with its fourteen senior officers, fifty clerks, and sixty inspectors,

exceeds in amount the whole strength of the office of the Secretary of State for the Home Department, and is quite insufficient to discharge the incalculable amount of work thrown upon it.

"Extreme centralization lies at the root of the whole matter. The officers of the Education Committee being the dispensers of large sums of money on principles determined by themselves, have taken care that for every pound so bestowed they have retained to the State a corresponding amount of power. The only limit to that power is their own organization, which cannot embrace the whole range of duties created and continually extended by its own agency. . . . . We have shown that it is an entire delusion to suppose that the Privy Council has any administrative powers or is qualified to exercise them. They are in fact exercised in the matter of primary education by the clerks acting in the name of that body." It would appear from what was stated at a recent public meeting in Dublin that the same thing occurs in the Department of Science and Art; official letters on important matters being written in the name of "My Lords," of the existence of which "My Lords" are often totally ignorant.

In addition to the seven or eight hundred School Boards, and the several millions of children in the Primary Schools, the President and Vice-President have to look after, they have in con-

nection with the Department of Science and Art the overseeing and government not only of the Elementary Schools of Science and Art throughout the United Kingdom; but also the Geological Survey of the United Kingdom; the Museums of South Kensington, Bethnal Green, School of Mines, Edinburgh, and the one of Science and Art, Dublin; the higher Schools of Art—viz., the Royal Hibernian Academy, the School of Art (Dublin) and the one at South Kensington; the College of Science (School of Mines) at South Kensington and Jermyn Street, and the one in Dublin; the Royal Zoological Society of Ireland; the National Library and Botanic Gardens, Dublin; and lastly, scientific research, consisting of the Royal Society Government Fund, £4,000 per annum, and the grant, £500 per annum, for Solar Physics.

In addition to these multifarious educational duties they are charged with the protection of the country from the inroads of infectious diseases at seaport towns. They must issue Orders in Council to subject the ships of particular countries to a rigorous quarantine, lest the crews should bring cholera on shore; and they must take the same energetic means of shutting out diseased cattle. It appears not only very absurd, but very comical, that Ministers who at one moment may be engaged in deciding on the question of research in Solar

Physics, should at the next moment have to issue orders that a cholera-stricken ship is not to enter our seaports; at another moment determining the constitution and government of one of our Colleges of Science and Art, or of one of our Art or Technical Museums, and immediately after directing their attention to the rinderpest. The necessity of transferring their attention to subjects so various and diverse cannot add to their efficiency in any one of the departments; the work of superintending Elementary Education alone, in the present day, ought to be no slight matter. At the time (May, 1874) the late Lord Hampton brought on his motion in the House of Lords on the necessity of having a Minister of Education, the *Daily Telegraph* remarked:—"It appears almost ludicrous to have Mr. Forster passing from elementary education to the rinderpest; now soothing the enmities of jealous Dissenters, and now calming terrified cattle-breeders. Mr. Lowe (Lord Sherbrooke) has perhaps forgotten that he was once a great authority on the rinderpest as well as on the Revised Code. A Department thus burdened with duties which are as remote from each other as the Poles, cannot be deemed a model of organization."

Divided *authority* can be no more a benefit in the matter of National Education than it would be in other Governmental Departments. That divided

authority exists there is no room for doubt, for the President and Vice-President do not bear the same relation to each other as a Secretary and Under-Secretary bear to one another. Lord Aberdare, who was once Vice-President, has admitted this—he said he considered he was responsible to Parliament; and many examples might be given to show the anomalous position of the President and Vice-President—as, for instance, the fact that in 1864 the Vice-President resigned in consequence of a vote of censure by the House of Commons on the Department, whilst the President remained in office.

We require a special Minister of Education for many weighty reasons:—

1. If we had an office under that name, the most competent person belonging to the Government party of the day would have to be selected for it, just as the most competent person has to be selected to fill the post of Chancellor of the Exchequer. It would, from the added importance, not be considered beneath the dignity of the most eminent of our statesmen to accept. As the *Times* observed in 1874, "a generation ago, we left education to take care of itself. A generation hence, the superintendence of education will be one of the most considerable domestic functions of the Executive Goverment."

2. The direction of National Education requires

to be entrusted to a single hand; for until we have *one* architect, with complete and undivided authority, our educational resources will not be utilized as perfectly as they might and ought to be, and the disorder that exists at present in our educational machinery will continue. It is true, progress has been made since the time the late Lord Lytton thus wrote:—"What a profusion of endowments! What a mass of iniquities! Let me once more evoke from the ill-merited oblivion into which it hath fallen the desolate and spectral instance of Pocklington School! Instance much canvassed, but never controverted! This school is largely endowed; it has passed into decay; its master possessed an income of £900 a year. How many boys do you think were taught upon that stipend? *One!* positively one! Where is the school itself? The school, sir—it is a saw-pit! Where is the schoolmaster? Lord bless you, sir, he is hiding himself from his creditors! Good Heavens! and is there no one to see to these crying abuses? To be sure, sir, the Visitors of the school are the Master and Fellows of St. John's, Cambridge. Now then, just take a drive to Berkhampstead; that school is very richly endowed; the schoolmaster teaches one pupil, and the usher resides in Hampshire!" We have certainly advanced since the time these iniquities occurred; but, as the *Times* remarked in 1874, "the administration of the

endowments for the support of secondary education throughout the country is scarcely inferior in importance to the supervision of primary education; and although the work of reorganizing these endowments now pursued by the Endowed Schools Commission may be expected after a time to cease, there will always remain the necessity of superintending their administration; and this should be the work of the Education Department, instead of being thrown upon the Charity Commission, the Home Office, and the Court of Chancery. It is impossible to realize Mr. Forster's ideal of primary schools everywhere within reach of the people, with grade schools to which the rising talent of the primary schools may be draughted, unless the working relations of every part of the structure to every other part are prevented from rusting by the watchful care of an undivided Department of Education. We need not go on to recapitulate the other branches of education, which are neither primary nor secondary, because we believe we have said enough to show that, as soon as the dimensions of the subject are adequately considered, it will be seen that the work the Executive Government undertakes to discharge in reference to education cannot be well done so long as it remains divided as at present. . . . . The Executive Government, partly through the operation of the principles of

Parliament, is charged with divers duties in relation to the means of education of the community, whether the education be primary, secondary, or academic, literary or scientific, artistic or technical, and these duties are divided among many persons, acting to a large degree in independence of one another. Is this a system to be maintained, or to be amended by collecting the discharge of allied duties together, and entrusting them to one authority? This is the question for Parliament to consider, and when it is really debated the answer will not be doubtful."

3. If we had a Minister of Education, it is more likely the causes of failure of different educational schemes and institutions would be inquired into and ascertained, and the experience thus acquired would be of service in preventing similar institutions being again started under the same conditions. In like manner, the marked success of any educational institution, or any department of one, would be more likely to come under his notice and be inquired into, and the knowledge gained be utilized in other institutions or departments of a similar kind. More efficient inspection and examination of schools might be looked for; no doubt a great change for the better has taken place since the Commissioners appointed to inquire into the state of popular education reported *that the junior classes of schools, comprehending the majority of*

children, do not learn, or learn imperfectly, the most necessary part of what they come to learn—reading, writing, and arithmetic. But Lord Sherbrooke stated not long ago, in the House of Lords, in connection with the subject of popular education, that he was accustomed to employ a boy to read to him, and it was rarely that he could meet with one who could read properly. No doubt examinations are better conducted now than they were then, although I saw by a Bradford newspaper the other day, that the School Board of that town were making complaints to the Education Department of the inspection and examination of their schools. One of the Commissioners, the late Mr. Senior, gave, in his work, "Suggestions of Popular Education," a specimen of the examination-papers of the Queen Scholars in 1857 and 1859. The *Edinburgh Review*, in commenting on them, said "it is impossible to conceive anything more extravagant than the range of questions addressed to these young persons, male and female, at this stage of their career; and on answering these questions, be it remembered, their success in life depends. A girl of eighteen or twenty is asked 'What events are associated with these places—Hobah, Beerkahai Roi, Mizpah, Peniel, Shalem Seechem, Luz? To give an exact and complete analysis of a considerable portion of one of St. Paul's Epistles; to give an analysis of the

Athanasian Creed; to describe the chief points of difference between the first Prayer-Book of Edward VI. and that now in use. In English History, to give some account of the minority of Richard II. and of the Treaty of Aix-la-Chapelle; and to explain, as to a class of children, the spring and neap tides. In the papers of 1859 the Queen Scholars are told to write a complete sketch of the reign of Edgar, and to give the terms of the Secret Treaty of 1670.' For this incredible mockery of common sense, we must suppose that the Lords of the Council, or their Examiners, are responsible, since these examination-papers are submitted to them, and, for aught we know to the contrary, prepared by them. We leave them, without another word of comment, to the judgment of the reader." Greater economy would also no doubt take place in our education departments. Mr. Matthew Arnold in his work on popular education in France, in alluding to the extravagance in printing and stationery in the Education Department in Whitehall, and in the Department of Science and Art, observes: "We may one day have to take a lesson from France in some of these respects. Not without doing violence to some crotchets, not without lopping off some elegant but superfluous branches of expenditure, will the plaything of philanthropists be converted into the

We will give some of the objections which were urged against Lord Hampton's proposal. The then Lord President, the Duke of Richmond and Gordon, said if the Lord President was relieved of education, there would be nothing left for him to do; he would sink down into a first-class veterinary-surgeon; but, as the *Daily News* remarked, "the Education Department was not created to give the Lord President work." The reason for the continuance of the present system, Earl Grey urged, appears to tell more in favour of, rather than against, a Minister of Education. He urged it is done in pursuance of the most ancient constitutional practice; but as all departments of the State were once governed by the Privy Council, if his argument was worth anything, it would be that all the different departments should be again governed by the Privy Council; but just as the system broke down with the other departments when the business of these departments became complex, so now the Education Department ought to be set free from the Privy Council for the very same reason. Earl Granville's objection to it appeared to be that it would increase the number of Cabinet Ministers, which he seems to consider a disadvantage; but it might be no more necessary to make the Education Minister a member of the Cabinet than it is to make the Postmaster General one. Certain

it is, that if the Newspaper Press is to be taken as the exponent of public opinion, the Public desire to have a Minister of Education.

We have pointed out in previous Lectures that written examinations are not the proper tests for ascertaining whether the examined have practically and usefully acquired a knowledge of any one of the Inductive Sciences. But before proceeding to explain the plan I propose for efficiently inspecting and examining what may be termed the Primary Science Schools of the Department, it may be as well to bring under the readers' notice a few special branches of expenditure of that Department. In the first Lecture we have given the total expenditure (£307,414) of the Department of Science and Art in 1879; we will now give a few details of the expenditure of the Science branch as far as we can separate it from the Art branch of the Department.

	1880–1.
Director of Science . . .	£900 going up to £950
Assistant Director of Science .	674 „ „ 750
Official Examiner . . .	350 „ „ 550
Assistant Official Examiner . .	350
Organizing Science Teacher . .	350

Science and Art:—

Inspectors of Schools from £400 to £500 . .	1,968
Occasional Inspectors	4,200
Lectures and Instruction to Science and Art Teachers in Training	2,000

	1880–1.
Local Committees for Examinations :—	
Special Local Secretaries and Assistants . . .	£1,700
Prizes—Science	3,000
Scholarships—Science	1,100
Grants in aid—for examples, School accessories, books, materials, and for purchase of drawings as examples of art, &c. :	
Science	2,800
Building grants, and examination of plans of local schools :	
Science	600
Expense of circulation to Schools of Science and Art, &c. :	
c, Science Division—viz., collection of objects for Education, Food, Animal Products and Building Materials	1,000
Technical and Special Assistants for Science and Art .	7,500

The above is far from a complete list, but it is sufficient to show that the annual expenditure on what may be termed the administration, examining and inspecting of these Primary Science Schools every year, is something considerable, and is constantly increasing; and if we could have added the cost of the Printing and Stationery the amount would have been considerably augmented. Mr. Matthew Arnold, who is, I believe, one of the chief inspectors of the Education Department has drawn attention, as I have already noticed, to the extravagance of Printing and Stationery in the Education Departments;

he thus comments on it: "There can be no doubt that a certain plainness and cheapness is an indispensable element of a plan of education which is to be very widely extended. In operations on a really vast scale, that rigid economy, even in the smallest matters, which in very limited operations may be thought overstrained, becomes an imperious necessity. . . . . Again, with respect to what may seem small matters of expenditure, it is impossible to over-estimate the saving which is effected in France, where administration is on so vast a scale, by a scrupulous economy in respect to these. Royal and imperial ordinances limit the privilege and guard against the abuse of official postage; stationery and printing, those great administrative agents, are under severe control. 'French administration is bepapered to death,' said a distinguished official one day to me—in English administration, also, paper plays no small part; but on how much more extravagant a scale! I have before me the form of report used by French inspectors when they visit a school. It is a single note sheet of ordinary paper, containing printed questions, over against which the answers have to be written. Within these iron bounds is the ill-appreciated but irrepressible eloquence of inspectors confined. An English inspector's visit to any elementary school expends six sheets and a half of excellent foolscap.

come to provide for the inspection of 65,000 schools, it makes a difference whether you devote to each six sheets and a half of good foolscap, or a single sheet of any ordinary note paper. Again, I take the item of *certificate examinations.* The charge for these in France is borne by the departments; under one sum is included the outlay for these, the outlay for cantonal delegacies, the outlay for premises for savings banks; all these being at the charge of the departments. In 1856 this item for the whole of France was under £2,000. For this sum, besides the other expenses mentioned, the certificate examinations requisite to meet the wants of a system of 47;000 schools employing certificated teachers, were provided for. What, in the same year, was the cost of our certificate examinations for a system of 6,000 schools? I am very curious to know, but unfortunately I cannot ascertain. The French, who are the best account keepers in the world, have an excellent plan of crediting each department with the cost of its own printing. It would be well, perhaps, if we followed their example; at present an English department has *its printing executed, its stationery provided, and in its estimates makes no sign.** But I remember the five days' paper-work of our

* There was this year (1881) a supplementary vote of £39,750 for stationery and printing; if Parliament or the Government are to have control over this expenditure, they must commence by having included in the estimates of each department the cost of its stationery and printing.

examinations—I remember the supplies of stationery—I remember the crowning operations of the Department of Science and Art.

Examination and Inspection of the Department Schools.—Most of my readers will know that the Department of Science holds examinations once a year in places where science classes in connection with the Department have been established; printed examination papers on the subjects to be examined upon are sent to the different places. The Department requires a local committee to be formed in each place where there are classes, and a special local secretary is appointed to assist them; he is paid for his labour; the amount paid to these local secretaries amounted in 1880–81 to £1,700.

Neither the Director of Science; nor the Assistant Director; nor the Official Examiners prepare the Examination papers; there are twenty-three Professional Examiners employed for this purpose, and they, aided by a number of Assistant Examiners, examine the answers of the examined. A large portion of the £7,500 under the head of Technical and Special Assistants is no doubt requisite to pay these Examiners and Assistant Examiners. Each school or class is also inspected by a body of inspectors; it would appear from the estimates I have given that there are four Permanent Inspectors for inspecting the Science and Art Schools; the united salaries of these inspec-

tors amounted in 1880–81 to £1,968; but in addition to these permanent inspectors there were employed to inspect the schools in 1878, 100 Engineer Officers; and in the estimates under the title of Occasional Inspectors, &c. &c., the pay for their inspection amounted in 1880–81 to £4,200. The prizes to the Science Students amounted in 1880–81 to £3,000. And I, like Mr. Matthew Arnold, am very curious to know what the printing and stationery required in these examinations cost the country.

It is a mistake to suppose that engineer officers are more fitted by education than other men for inspecting and directing scientific education; they no doubt receive a good mathematical education; but any one who has had to do with the teaching of any of the Inductive Sciences knows that with respect to these sciences they do not require very advanced knowledge to pass their examinations in these subjects; military men are also unfitted by their training to be educationists; no one would dream of giving an educationist a military position, and it is equally undesirable and unadvisable to place military men in educational positions. Clergymen would be far more fitted for the inspection of the schools than these officers, and a clergyman competent for it might be met with almost in every place where a class was started. But it is admitted

inspection and examinations ought to be united, and in no branch of study is the union of the two more necessary than in the examination of students in the Inductive Sciences.

Observation and experiment being the fountains of these Sciences, written examinations cannot be converted into efficient tests as to a student's attainments in any one of them ; and we have shown by examples the injurious effects which may result from smatterers in science being engaged in industrial establishments. The Departments is yearly passing a large number of young men who have simply acquired a certain amount of theoretical knowledge in some one or more of the Inductive Sciences, and in conferring on many who pass prizes, medals, and certificates for the acquirement of this unpractical knowledge, These Department's honours are likely to mislead those owners and directors of industries who from a want of scientific knowledge themselves cannot distinguish between the genuine man of science and one who has only acquired a little theoretical knowledge of it. If the aim of the President and Vice-President of Education be to make these State-instructed students in science capable of taking their part in the improvement of our industries and in the invention of new ones, they must entirely alter the existing system, and the

stated some time ago that he considered it as little better than *scratching the ground.*

By making use of the various Colleges which are now established in different parts of the kingdom, a more efficient inspection and examination of the Primary Science Schools could be carried out than now exists. For this purpose I would divide the United Kingdom into districts, and I would assign the examination and inspection of the Science Schools in the district to the Professors of the College in that district. The advantages of this individual inspection and examination of each school at the school itself over the existing system, are many and important.

The examinations could be entirely, if desired, of a practical character; and the teachers in these schools who would have less experience and extended knowledge of their subjects than the College Professors, would be greatly assisted by coming in contact with them. They would be able to apply to those more conversant with the subject for instruction in their difficulties; for suggestions as to the improvement of the working processes; and the College Examiners would see with their own eyes whether the work of practical instruction was efficiently carried on. Both examination and inspection would not only be better done than at present, but it would be more economical in a money point of view, and the cost of inspection and

City Guilds having their classes inspected by these College Professors at the same time. Another and very important advantage to be gained by this diversity in the examinations would be, that we should not be casting so many of our young intellects into the same mould as we are doing at present. Moreover, the teacher would be able to throw into his teaching more individuality and intelligence, and by diversity in examination we should not be pulling all our science students "through holes of the same size, after the fashion of manufacturing wires." "One great evil," states Dr. Playfair, "of University education, and still more of University examination, is to create *faithful disciples rather than independent thinkers.* The diversity of teaching in different Universities tends to mitigate this evil, but the uniformity of *a common system of examination vastly augments it.* When the Government takes graduation in hand, and stamps our intellects, as it does its sovereigns, with one uniform die, the power at its disposal will be immense; but, as in France, the intellects will in time be crushed under the stroke, and then will not be worth the coining."

One distinguishing peculiarity of German chemical schools is the great diversity of chemical education they offer. The laboratories presided over by Bunsen, Hofmann, Kolbie, Fresenius, and others, have each their distinguishing features.

Fresenius, Bunsen, and other distinguished German chemists have not accepted the new views in the science for the inorganic portion of it. Here in England teachers could display no such independence of thought, they have to walk themselves and make their pupils walk in the paths of science the examiners walk in, although they may not approve of it.

There is a continual lamentation that our Science Schools are so far behind those of Germany, and the lamentation is frequently followed by a further application to the State for increased money grants; but whilst lamenting the inferiority of our schools, we do not copy some of the excellencies of the German system; we foster servile views of education in the minds of our pupils by having annual scrambles for prizes, medals, money, &c., they exclude the principle of *competition* as tending to foster those servile views, and causing spasmodic and exhausting efforts and feverish excitement *rather than the healthy and harmonious development of the mental powers.* Our young men no more require to be urged to study by the prospect of reward in the shape of prizes of some kind or another, than do German youths. Englishmen, by contributing so generously and unselfishly for the extension of education, show that they love learning; and the same feeling prevails in English youths; although it has been attempted to ex-

tinguish it in our young men by engaging them in annual money scrambles. Let the system of prize giving be abolished in our Science Schools, and let inspection and examination of them be combined, we shall then have a more healthy condition in these Institutions. But one other alteration is required to complete the required reforms, and that is to discontinue the system of payment on results, and substitute for that kind of payment by the State capitation fees, and let the teacher also look to the fees of the pupils for further payment. It may be said by some, that if payment by results is abolished, the teacher will neglect his pupils; in fact he will not perform the work he undertakes to do. Why should the teacher be more dishonest than secretaries and clerks; the latter are trusted, they are paid fixed salaries, why cannot the poor teacher be trusted?

I estimate that at least £20,000 a year would be set free, from the situations that would be abolished or mimimized if these reforms were carried out, for the payment of the capitation fees to the teachers, and for the inspection and examination of the schools in the way proposed.

There is yet one other reform in connection with the Department of Science which is urgently required. I need not go into all that has taken place, two years and more ago, in connection with that Department, to prove the necessity of the Minister

of Education being aided by Counsellors who are distinguished both as Educationists and Scientific men. It may be said in reply that the Minister does avail himself when he requires such aid, of the advice of men of science; but there is a wide difference between consulting irresponsible and responsible persons. Let the President and Vice-President follow the example the Secretary of State for War has set them in the formation of the new Ordnance Committee. Other nations are abreast of us in industrial enterprise, and are in front of us in the matter of education; we must, therefore, adapt our educational institutions to the wants of the time, and this is not likely to be accomplished unless we have a Minister of Instruction aided by proper Counsellors.

APPENDIX I.

Page 18.

Diagrams of Austrian and Bavarian Instruction.

THE French Commissioners, in their Report, which was republished by the English Government, on Technical Instruction in Germany and Switzerland, gave a diagram, which I give in the form of a genealogical tree on page 452, giving a synopsis of the arrangement of the State educational institutions in Austria. "It has been copied," they state, "from a report on the schools of Vienna (*Bericht über die Ausstellung von Schul und Unterrichts-Gegenständen in Wien*), presented in 1862 to the Chevalier de Schmerling by Baron Helfert.

"In this diagram we see clearly represented the system, still so imperfectly understood in England and France, of the separation of the pupils. Thus, after following their elementary studies together as far as a certain point, they take different directions, some going to gymnasia to continue those of literature, others to the practical schools specially intended for the study of the applied sciences.

"In the gymnasia a similar separation takes place. Their lower classes prepare pupils for the schools of apothecaries, druggists, the veterinary art, and clerkships, as well as for the lower agricultural, forest, mining, commercial, and industrial schools, whilst the upper classes lead to the universities and studies of a high order, to the faculties of Catholic theology, law, medicine, and philosophy, or in other cases to the Protestant, Greek, or other theological schools, and to what are

called the academies of law, of oriental languages, and of rabbis. Lastly, these higher gymnasia also send pupils to the polytechnic institutes, and to the forest, mining, and agricultural academies.

"In like manner, the practical schools are divided into two categories; those of the lower order also lead to the special school for agriculturists, forest officers, miners, merchants, and manufacturers; those of the higher degree direct their pupils towards the polytechnic institutes, and thence towards the special divisions of civil constructions, bridges and roads, applied mechanics and chemistry. In common with the higher gymnasia, they also lead to the academics for agriculture, forests, mines, and especially to those for the navy and commerce.

"On the other hand, we see part of the children who have attended the primary schools proceed directly on leaving them to special practical schools of a humbler kind; as in the case of females, to the schools of midwifery, the higher schools for girls, and the normal for governesses; while the boys go to the Sunday schools, the schools for agriculturists, vine-growers, gardeners, pilots, and miners. In the same rank as the primary schools, but distinct from them, stand the asylums which receive the blind and deaf and dumb.

"Besides these there are establishments of a totally different kind—viz., those devoted to the fine arts, such as the Conservatory of Music, with its schools of elocution, singing and instrumental music, the academy of fine arts, and the schools of painting, architecture, and sculpture.

"This summary exhibits a comparatively organized system of education meeting all the requirements of the different classes of individuals of whom society is composed, and allowing every one to acquire, for the most part at little cost, the instruction suited to his

capacity and position, which enables him at once to enter on the active duties of life."

Synoptical View of Education in Bavaria.*

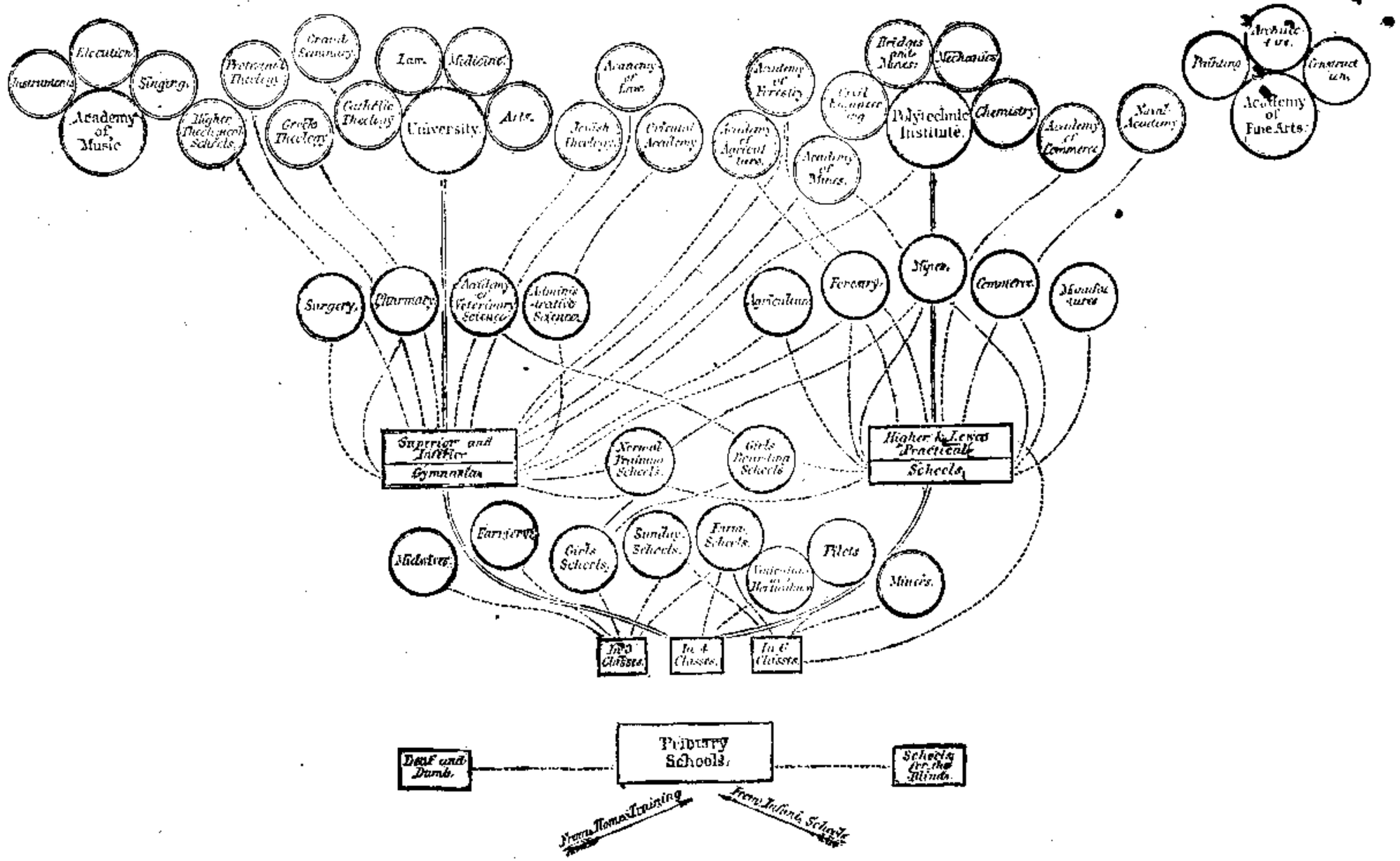
"The diagram on page 453 represents, under the form of a genealogical tree, the connection and subordination of the different branches of instruction as at present organized in Bavaria, from the primary school to the highest educational establishment. It thus describes the schools which are under the direction of the Ministry of Public Instruction, and those which are under the Ministry of Commerce and Public Works.

"The duration of the studies being indicated for each subdivision, it appears:—1. That, at fourteen years of age, a boy may begin his apprenticeship with an adequate preparation of seven or eight years' elementary studies. 2. That, at fifteen, he may have acquired the instruction necessary for trade assistants, farmers' sons, and clerks in manufactories. 3. That after four years' elementary study of Latin, and four more years of literary and scientific in a real gymnasium—that is, eight years after leaving the primary school, or at the age of eighteen, a young man may be admitted to the polytechnic institutes, which he will leave four years later, being then twenty-two, with sufficient technical instruction to enter the public services of bridges and roads, mines or forests, or to become a mechanical engineer. All the preceding branches of instruction, after leaving the primary school or the elementary Latin school, are dependent on the Ministry of Commerce and Public Works.

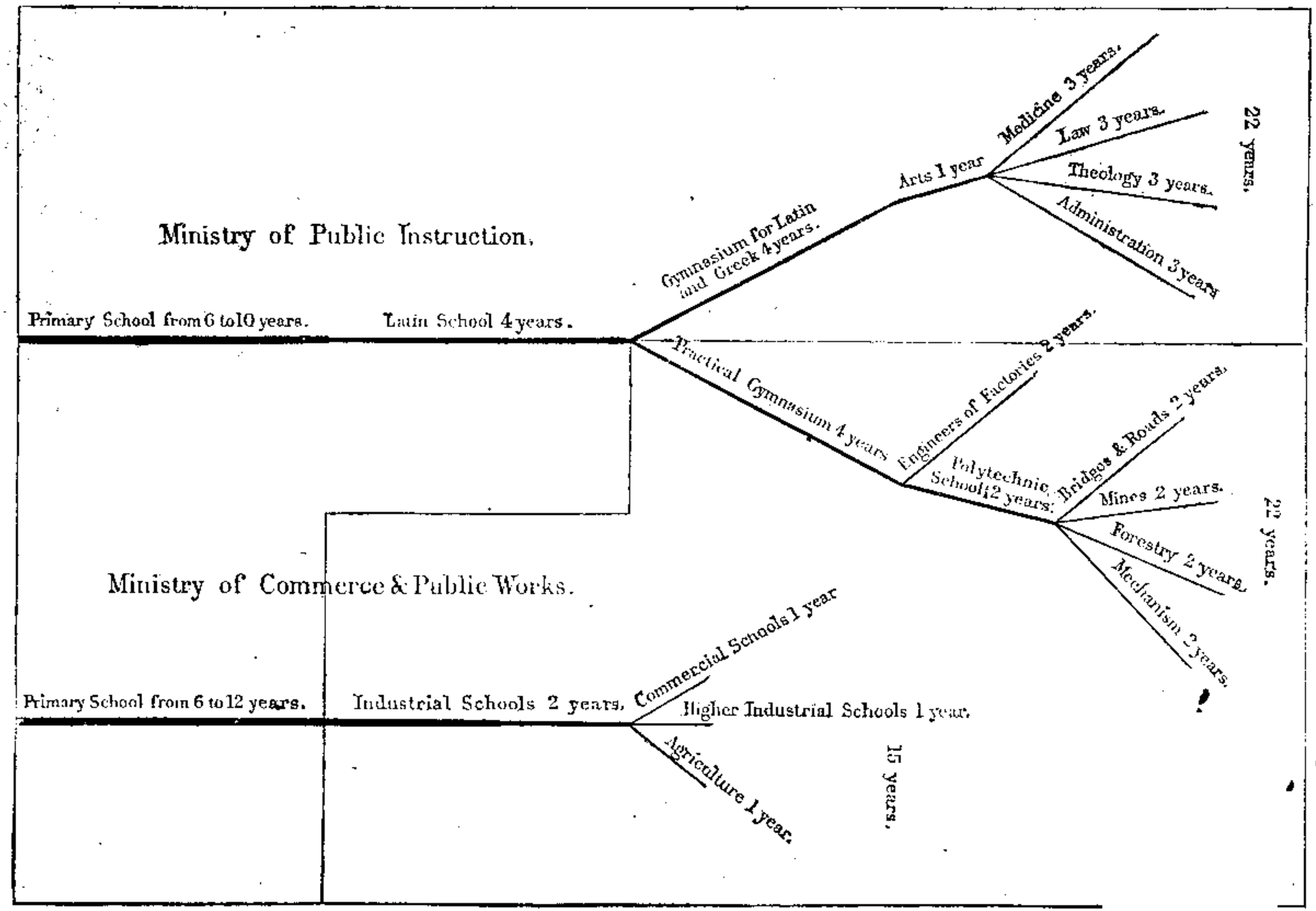
"On the other hand, under the direction of the Ministry of Public Instruction, the primary schools, the elementary Latin schools of four years' study, the literary gymnasia of the same duration, followed by one year of

* This synoptical view and diagram of Bavarian education is also taken from the French Commissioners' Report.

Diagram of the Arrangement of State Education in Austria.



Division of Subjects of Instruction between the Department of Public Instruction and that of Commerce and Public Works, Bavaria, 1864. (New Arrangement of Studies.)


Ministry of Public Instruction.
Primary School from 6 to 10 years.
Latin School 4 years.
Gymnasium for Latin and Greek 4 years.
Arts 1 year
Medicine 3 years.
Law 3 years.
Theology 3 years.
Administration 3 years
22 years.
Practical Gymnasium 4 years
Engineers of Factories 2 years.
Polytechnic School 2 years.
Bridges & Roads 2 years.
Mines 2 years.
Forestry 2 years.
Mechanism 2 years.
22 years.
Ministry of Commerce & Public Works.
Primary School from 6 to 12 years.
Industrial Schools 2 years.
Commercial Schools 1 year
Higher Industrial Schools 1 year.
Agriculture 1 year.
15 years.

philosophy, lead a young man, at nineteen years of age, to the faculties of medicine, law, and theology, which require three years' studies, and to that of administration, which takes two years; so that, in these directions, complete studies may be terminated at twenty-two, or even twenty-one years of age.

"The whole arrangement of the plan of studies at present adopted in Bavaria appears to satisfy all the requirements of literature and science, as well as those of manufactures, trade, and agriculture. It moreover easily admits of all the additions which may be desirable for certain industries or local requirements, such as Sunday and evening schools for workmen, special higher schools for girls, apprentice schools, normal schools for teachers of either sex, &c., which we have not here mentioned."

APPENDIX II.

Page 49.

Madder Dye.

THERE is a style of dyeing, one of the madder styles, called Turkey red or Adrianople red, so called because this style of dyeing was introduced into Europe from the East; and although it is one of the most difficult and complicated of the dyeing processes, it must have been known at a very early period, as the red dye of the cloth wrapping the Egyptian mummies is Turkey red. Although all the Lancashire calico-printers could dye Turkey red (I am now speaking of some years past) they could not rely upon obtaining constantly the same tint, which was so necessary for the dyed goods, especially those intended for the Mahomedan countries, the great market for that style of dyeing; therefore many, or I might say most, of the calico-printers, at the time I speak of, sent their cottons to be dyed Turkey red to the specialist in this style of dyeing.

The dye drug employed for Turkey red is called madder; it is the root of a plant called *Rubia tinctorum*. Owing to the dyer being able to produce with madder, by the use of different mordants,* a vast variety

* Coloured substances employed in dyeing are divided into two classes, the substantive and the adjective. The substantive colours are those which, being very sparingly soluble in water, and having a strong affinity for the fibre of the cloth, combine directly with it. The adjective colours are incapable of so permanently fixing themselves, and the necessary insolubility and affinity for the cloth is given through the intervention of a substance which has an affinity

of colours and tints, and all these different colours possessing a degree of permanency which no other dye-wood produces, madder dyeing is therefore more important than other kinds of dyeing, and it is at the same time the most difficult and complicated. Madder, for these reasons, has been the subject of more numerous chemical investigations than any other dye-drug, in order to discover not only the dye substances it contains, but also to ascertain their composition; by these investigations it has been discovered that the finest and most permanent of these substances in the root is one to which the name alizarine has been given.

Two chemists, Grebe and Lieberman, were led by a series of one of the most beautiful chemical investigations, which I will not sketch out to you on the present occasion, to the conclusion that alizarine, the finest of the dyes in madder, and one of the solid hydrocarbons * in coal tar, which has been named anthracine, stood in very close constitutional relation. They succeeded first in converting alizarine into anthracine, and afterwards they succeeded in converting anthracine into alizarine. This was the first instance of the artificial production of a vegetable colouring matter. As I have intimated, it was by no chance experiment that alizarine was artificially produced. It was actually constructed by following out the indications of a theory of its molecular structure to which a study of its reactions and those of allied compounds had led. I must further observe that the artificial alizarine is no laboratory curiosity, but is now manufactured as a dye; and it has so far supplanted madder that in many dye-

for the colouring matter, and likewise for the cloth. A substance possessing these properties is termed a *mordant*. By varying the mordant, not only different shades of colour, but different colours, can be obtained from the same dye-drug.

* Compounds composed of the elements carbon and hydrogen only.

works the root is no longer used, and in others it is used in greatly decreased quantities, for the artificial dye has many advantages over madder. There is, for instance, a saving of time in employing it, and the dye is purer and more concentrated. This great change in madder dyeing has taken place in the last half-dozen years.—*Extract from the Lecture referred to.*

APPENDIX III.

Pages 234 and 322.

These Letters on the application of Arithmetical Problems to Chemical subjects, and on Chemical Examinations, were published in the "Chemical News" some years ago.

Chemical Problems.

To the Editor of the "Chemical News."

Sir,—

I observe in your review of Professor Thorp's work on "Chemical Problems" a slight inaccuracy, which I hope you will allow me to point out. You state you "believe that Dr. Roscoe was one of the first to recognize the value of such questions." I, on the contrary, believe that I was the *first* to introduce them. In 1851 the first edition of my "First Step" appeared, which was the first work, as far as I am aware, devoted to chemical problems, and I had for some years before the publication of it, employed the problems in my classes. When I had the work ready for the press I sent a copy of the arithmetical questions to my friend Dr. Frankland, who was then Professor of Chemistry at Owens College, and he wrote to ask my permission to make use of them in his classes before the work was published, which I readily granted; and he and Dr. (now the Right Hon.) Lyon Playfair were the first to employ them after its publication. In my "Second Step," which appeared in 1863, which was prior to the publication of Dr. Roscoe's "Chemistry," I gave an advanced course of chemical problems.

It has been a pleasure to see the problems so extensively employed, as I believe they have effected some improvement in chemical examinations; and I hope the new class of questions I have given in the last edition of my "Qualitative Analysis" will be adopted, as I believe they would put a stop to the cramming system which is now unfortunately so prevalent, and which is so ruinous to all real mental culture.

But the examinations in practical chemistry are, I think, in a worse position at the present time than the written examinations; and I think if you would allow an interchange of opinions through the columns of the *Chemical News* on this subject, it would conduce very much to the progress of the science. I will, with your permission, commence this interchange in another communication.

I am, &c.,

ROBERT GALLOWAY.

ROYAL COLLEGE OF SCIENCE, DUBLIN,
December 19, 1870.

EXAMINATIONS IN CHEMISTRY.

To the Editor of the "Chemical News."

SIR,—

As you have kindly allowed the interchange of opinions on examinations in practical chemistry, I desired in my former letter to take place through the *Chemical News*, it devolves upon me to commence the interchange.

It will not be denied that practical examinations in purely experimental sciences, *if they are given at all*, play a very subordinate part in the examinations in these sciences, and this at a time when examinations are so extensively employed as tests of proficiency. Hence, compared with the written examinations, very little

thought or attention has been devoted to them; consequently they are not in unison with the present state of these sciences. In chemistry very little has been done beyond giving examinations in qualitative analysis, and these examinations are frequently so trivial that they are limited to one or two bases, and the like number of acids.

I recently conducted in this College some examinations in practical chemistry. I gave to the junior students a complex mixture, to be examined qualitatively; to the more advanced students, one in quantitative analysis, and one in assaying. The remarks which follow apply to the two latter examinations. In both cases the students were limited as to *time*, and there was *variety* as regards the substances to be estimated. I intended to make these examinations, as regards conditions, &c.—and I think I succeeded in making them—more severe than those a young chemist would encounter if he was engaged as an analytical chemist, or if he was appointed chemist in some chemical manufactory. And in this point of view I have not seen any examinations equal to them—not even the practical examinations for the degree of Doctor of Science in the London University, which are the most advanced I have seen, although I think far inferior to what they ought to be for such a degree examination. It is in the extent and conditions of the examinations I think an interchange of opinions would be so useful. I send a copy of the printed papers as being the most satisfactory mode of proceeding. In the instructions it will be seen that six hours were allowed for both papers, but I may add that they were completed by the students in five hours, and most satisfactorily.

Subject—Quantitative Analysis—Practical Examination.

General Instructions.—The same value is attached to each determination. Six hours are allowed for the

analyses. The percentage amounts of the substances determined to be given in each case.

(1) Find the amount of chloride in the sample of chloride of lime given you, by means of a standard solution of arsenious acid.

(2) Determine by means of the polariscope the amount of sugar in the sample of cane sugar given you.

(3) Estimate the amount of soluble phosphate in the sample of superphosphate given you.

(4) Find the "original gravity" of the *porter* given you for examination.

(5) Determine the amount of *peroxide of manganese* in the sample of manganese ore given you.

Subject—Assaying—Practical Examination.

General Instructions.—The same value is given for each assay. Six hours are allowed for the assays. The percentage amounts of the substances determined to be given in each case, No. 4 excepted.

(1) Determine by wet assay the quantity of iron in the sample of iron ore given you.

(2) Determine by dry assay the quantity of lead in the sample of lead ore given.

(3) Determine by cupellation the quantity of silver in the button of lead obtained in the lead assay.

(4) Determine by Lewis Thompson's method the absolute heating power of the sample of coal given you, and state how much water at 212° F. will be converted into steam by the coal.

(5) Determine by wet assay the quantity of copper in the sample of copper ore given you.

I am, &c.

ROBERT GALLOWAY.

ROYAL COLLEGE OF SCIENCE, DUBLIN,
December 27, 1870.

As the study of qualitative analysis leaves still something to be desired in the practical education of the junior students in chemistry, I intend in future to give, in addition to the examination in qualitative analysis, an examination in the preparation of inorganic compounds, by giving to each student an ore from which he must not only prepare two salts of the chief metal it contains, but must return them in due weight. The amount of metal in the ore will be determined before it is given to the student, so that his results may be checked, and according to the amount returned will be the number of marks given.

To those advanced students who will not have time to engage in original research I purpose giving them bodies like compound ethers, to examine and determine the composition of the acid and basic radicals they contain.

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